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PLAN FOR THE STABILIZATION AND REMOVAL OF WALL
PAINTINGS AT ÇATALHÖYÜK

Catherine E. Turton

A THESIS

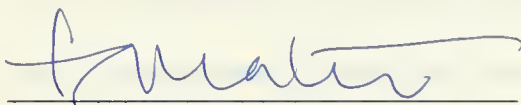
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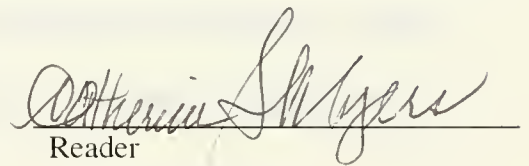
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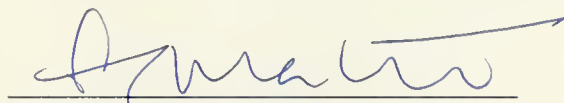
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Chapter 1: Introduction

1.1 Statement of Purpose

This research aims to develop methods for the emergency stabilization and removal of the wall paintings on earthen plaster at Çatalhöyük, a Neolithic settlement located on the Konya Plain in south central Turkey. The site, first excavated in the 1960s by James Mellaart, represents one of the earliest known examples of a society in transition from an economy based on hunting and gathering to one based on the domestication of plants and animals. Neolithic mudbrick walls coated with multiple layers of earthen plaster, wall paintings, and elaborate plaster reliefs are part of the extensive physical evidence revealed at Çatalhöyük that has served to dramatically alter traditional views of prehistoric Anatolia and the Near East in general.

Mural paintings discovered at Çatalhöyük are some of the earliest yet found on man-made walls. Continued excavation of the site, combined with its increased exposure to the elements will inevitably result in the destruction of building fabric. The impending loss of any remaining paintings required an evaluation of methods for the transfer and reattachment of the painted plasters. Due to its invasive nature, the detachment of wall paintings is a controversial conservation intervention. However, our ability to comprehend the historical and aesthetic information presented in these superimposed

paintings depends both upon their state of conservation, and our understanding of how they may have been altered due to the effects of both time and man.¹ An extensive research program for the conservation and separation of the mural paintings was carried out at the Architectural Conservation Laboratory of the University of Pennsylvania. The project began with an overview of conservation literature focusing on detachment techniques (See Appendix B). A facsimile type was developed for laboratory testing prior to on-site treatment testing.² Executed on 6-by-6-inch and 12-by-12-inch gypsum board and terra cotta tiles, the samples consisted of 14 layers of plaster and paintings using materials similar in character to the original painted plasters. Treatments and materials were selected based on the following criteria: characterization of the plasters including optical and physical properties; identification of on-site deterioration mechanisms; performance of various treatments under controlled conditions; and the compatibility of selected materials and treatments as tested on the facsimile paintings.

¹ For further information on conservation and detachment techniques, see Paolo Mora and Laura Mora, *Conservation of Wall Paintings* (London: Butterworth's, 1984).

² Plaster characterization consisting of a series of tests including bulk sample and microscopic examination, cross and thin section examination, scanning electron microscopy with energy dispersive spectroscopy, chemical analysis, and granulometry was carried out by Evan Kopelson and described in, "Analysis and Consolidation of Architectural Plasters from Çatalhöyük, Turkey" (master's thesis, University of Pennsylvania, 1996), 95-97.

Based on knowledge of the site, testing considered the following conditions and treatment requirements:

- Surface consolidation of powdering paint and plasters
- Interlayer detachment/preconsolidation
- Consolidation of the earthen plasters
- Evaluation/selection of facing adhesives for mural detachment
- Evaluation/selection of detachment methods
- Compatibility of treatments

Visual assessment and standardized tests, developed by the American Society for Testing and Materials (ASTM), CRATerre, and the Federation of Societies for Coatings Technology were used to evaluate methods and materials.

Following a comprehensive study of both traditional and modified methods and materials, two levels of detachment were selected, researched, and ultimately tested on the laboratory facsimiles. These techniques, known as *strappo* and *stacco*, were originally developed in Italy for the detachment of paintings on lime plaster. *Strappo* refers to the detachment of the paint layer alone; *stacco*, to the detachment of the painted surface including the underlying plaster layer. A third technique, *stacco a massello*, refers to the removal of entire walls.³

³ This technique was considered in a separate phase of research.

1.2 Current Research

In 1993, Çatalhöyük was reopened as a full-scale excavation by the Çatalhöyük Research Trust, under the auspices of the British Institute of Archaeology at Ankara. Current excavation, headed by Ian Hodder of Cambridge University, aims to continue archaeological research and to develop a program for tourism and heritage management. Excavation will be carried out over the next twenty years.

For the past three years, the Architectural Conservation Laboratory of the Graduate Program in Historic Preservation of the University of Pennsylvania has undertaken a research program, currently under the direction of Frank G. Matero, Lindsay Falck, and Catherine Myers, to develop an integrated architectural conservation program at Çatalhöyük. The research has focused on a broad range of issues: the *in situ* stabilization of wall paintings, plaster reliefs, and whole buildings; the development of non-destructive transfer methods for the wall paintings, reliefs, and architectural elements; and the development of techniques for the separation of multiple layers of wall paintings. Additional research carried out at the Architectural Conservation Laboratory includes the development of apparatus for the detachment, removal, and transport of the architectural elements, by Professor Lindsay Falck and Caitlin Moore. Also contributing to this research is a thesis by Elizabeth Moss which explores the environmental alterations to plastered mudbrick walls during excavation and methods for mitigating their effects. The relevance of this type of comprehensive research program is global.

The remainder of this introduction will establish a context for the chapters that follow, beginning with a brief description of the location of the site and prevalent environmental conditions. A summary of architectural features and a cursory description of the population are included to further understanding of the context within which the wall paintings were created. The second chapter, "Sample Development," describes the development of prototype and preliminary test samples. Chapter 3, "Testing Program" describes the preliminary testing program, the assessment of results, and the procedure and results for the detachment of the prototype samples. Chapter Four, "Final Results," offers an assessment of data, draws conclusions, and presents recommendations for further study. Appendix A offers a summary of the treatment history of the painted plasters at Çatalhöyük. Appendix B provides a brief historical background of detachment techniques and a compilation of case studies reflecting traditional and modified methods for the detachment of mural paintings from a number of substrate materials.

1.3 Çatalhöyük

The site consists of a double mound formation known as Çatalhöyük East and Çatalhöyük West. It is situated nearly 3000 feet above sea level, on the Konya plain, the largest alluvial plain in Turkey, approximately 14 km north of Çumra, in south central Turkey.

Considerable seasonal temperature changes are common. The semi-arid climate may range in temperature from freezing in the winter to greater than 20°C in the summer.

Rainfall is normally under 300 mm per year.⁴ The landscape of the Konya Plain is dominated by the volcano, Kara Dag, to the south and by the Taurus Mountains to the west. The Çarsamba Çay, its main water source, presently splits beyond Çumra into three branches. Geoarchaeological investigations indicate that a distributary of the Çarsamba River ran between the eastern and western mounds at Çatalhöyük, and that the site itself lies in the former bed of a Pleistocene lake.

Regional soil studies conducted by Driessen and de Meester in the 1960s indicated this area as a former backswamp.⁵ The soils were classified as Class II, “good soils with moderate limitations or risks of damage,” in other words, adequate for agricultural uses.⁶ Location of the settlement at the junction of two different types of Çarsamba fan soils, one suitable for irrigation, the other not, has been compared to the relationship between settlement location and soil distribution found at other ancient sites.⁷ Game may have been attracted to the moist soil, while the adjacent soil, moistened by capillary action, could have supported the production of grains. Research by Ellison and Harris conducted in southern England sustains the notion of a link between settlement site and the juncture of different

⁴ Neil Roberts, Peter Boyer and Romola Parish, “Preliminary Results of Geoarchaeological Investigations at Çatalhöyük” in *On the Surface: Çatalhöyük 1993-95*, Ian Hodder, ed. (Cambridge: McDonald Institute for Archaeological Research; London: British Institute of Archaeology at Ankara, 1996), 19.

⁵ Ian Todd, *Çatal Hüyük in Perspective* (California: Cummings Publishing, Inc., 1976), 113.

⁶ P.M. Driessen and T. de Meester, *Soils of the Çumra Area, Turkey* (Holland: Centre for Agricultural Publishing and Documentation, 1969) quoted in Ian Todd, *Çatalhöyük in Perspective* (California: Cummings Publishing, Inc. 1976), 114.

⁷ Todd found a correlation between this relationship and one discussed by Webley regarding certain Palestinian sites, found in areas containing two different soil types. D. Webley, “Soils and Site Location in Prehistoric Palestine” in E.S. Higgs, Ed. *Papers in Economic Prehistory* (Cambridge: Cambridge University Press, 1972) 169-180, referred to in Ian Todd, *Çatal Hüyük in Perspective* (California: Cummings Publishing, Inc., 1976), References: 114, 163.

soil types.⁸ Examination of excavated material-faunal remains, paleoecological data, and soil studies-corroborates the concept of a settlement with an economy based on domesticated cattle, hunting, agriculture, and trade.⁹

The Architecture

Discovery and initial excavation of this site, begun in the 1960's under the direction of James Mellaart, covered a thirtieth of the 16-hectare east mound, and revealed a sophisticated Neolithic settlement dating to the seventh and sixth millennia B.C.¹⁰ This is the largest-known early prehistoric settlement in the Near East with the most extensive area of architecture as yet uncovered for the period. Its location and the abundance of natural resources favored the existence of a seemingly continuously stable settlement. Evolution of this culture is believed by Mellaart to have continued, undisturbed, for a period of at least 800 years.

The most studied mound, the East Mound, is approximately twenty-three meters high and measures approximately 600-by-350-meters in size. It is believed that Mellaart's excavation revealed fourteen building levels dating from the eighth and

⁸ A. Ellison and J. Harris "Settlement and Land Use in the Prehistory and Early History of Southern England: A Study based on Locational Models" in D.L. Clarke, Ed. *Models in Archaeology* (London: Methuen, 1972) 911-962, referred to in Ian Todd, *Çatal Hüyük in Perspective* (California: Cummings Publishing, Inc. 1976), References: 163.

⁹ Todd, *Çatal Hüyük in Perspective*, 119.

¹⁰ The smaller western mound appears to be predominantly Chalcolithic in date. The discovery of Neolithic remains continuing under this mound indicates that the two may have formed one big settlement ranging over 50 to 60 acres. If this is true, it is the largest Neolithic site known in the Near East. From James Mellaart, *The Goddess from Anatolia* (West Germany: Udo Hirsch, 1989) Vol.2, 6. The disturbances of a Hellenistic occupation and later manipulation of the mound for agricultural use have hindered detection of subsurface architecture. Roger Matthews, "Surface Scraping and Planning" in *On the Surface: Çatalhöyük 1993-95* Ian Hodder, ed. (Cambridge: McDonald Institute for Archaeological Research; London: British Institute of Archaeology at Ankara. 1996). 99.

seventh millennia B.C.¹¹ The East Mound is almost completely Neolithic, exhibiting evidence of Hellenistic, Roman, and Byzantine disturbances in discrete locations.¹² The site has suffered extensive deterioration since its closing in 1965. Neolithic walls have collapsed, large sections of plaster have been exposed, and the tops of walls have been worn away by the foot traffic of tourists. A massive irrigation program has lowered the water table causing the loss of organic materials previously preserved in waterlogged conditions.¹³

Excavation of the eastern mound at Çatalhöyük revealed a large village, the architecture largely intact. The settlement appears to have evolved over time, exhibiting an organic, cellular development nearly devoid of right angles, rather than planned growth.¹⁴ Most of the buildings were plastered and painted numerous times. Wall paintings, some of the earliest yet found on man-made walls, are super-imposed on, and often separated by many campaigns of undecorated plaster. The sense of order and plan evident in the layout at Çatalhöyük suggests the existence of established customs and standards.

Buildings were constructed of unbaked mud brick, usually up to or over one meter in length, made from local alluvium and occupation sediments mixed with vegetal

¹¹ The exact number is currently in dispute.

¹² For further information, see Roger Matthews, "Surface Scraping and Planning" in *On the Surface: Çatalhöyük 1993-95* Ian Hodder, ed. (Cambridge: McDonald Institute for Archaeological Research; London: British Institute of Archaeology at Ankara, 1996), 81.

¹³ Ian Hodder, ed., *On the Surface: Çatalhöyük 1993-95* (Cambridge: McDonald Institute for Archaeological Research; London: British Institute of Archaeology at Ankara, 1996), 2.

stabilizers. In some cases, the mortar layer is as thick as the mud bricks. The houses are timber-framed and have squared oak post and beam construction with mud bricks filling the openings between the posts. Timber was also used in the construction of roofing, verandas, and paneling.

Generally, changes in mud bricks and mortar correspond to changes in floor and building levels. Although evidence suggests that different types of bricks were used concurrently during the construction of a wall, these variations, coupled with a slight overhang between one level and the next often indicate the construction of new walls directly atop earlier ones following the orientation of previous buildings. In such cases, both sections were usually rendered with a continuous layer of plaster. Examination of these plasters revealed two different types.¹⁵ One was an earthen plaster, and the other, a finer marly type, was probably obtained from the Pleistocene lake bed.

Multiple applications of white wall plaster, as well as elaborately prepared plaster features and niches, are common. Plastered posts and the lower panels of houses were either painted red all over or just red for the posts, or with a pattern on the lower panels.¹⁶ In many instances, multiple layers of red painted plaster were found within the white plaster sequences on walls, floors, platforms and benches. Paintings were generally

¹⁴ Roger Matthews, "Surface Scraping and Planning" in *On the Surface: Çatalhöyük 1993-95*, Ian Hodder, ed. (Cambridge: McDonald Institute for Archaeological Research; London: British Institute of Archaeology at Ankara, 1996), 85.

¹⁵ Wendy Matthews and Shahina Farid, "Exploring the 1960s' Surface: the Stratigraphy of Çatalhöyük" in *On the Surface: Çatalhöyük 1993-95*, Ian Hodder, ed. (Cambridge: McDonald Institute for Archaeological Research; London: British Institute of Archaeology at Ankara, 1996), 275-276.

¹⁶ James Mellaart, *Çatalhöyük: A Neolithic Town in Anatolia* (New York: Mc-Graw Hill Book Company) 149.

executed above the main platforms of the north and east walls, although they occasionally stretched around corners to adjacent walls.

Plaster floors were made from alluvial and lake-derived deposits with particle sizes ranging from silty clays to medium coarse sandy silt loam.¹⁷ Similar materials were used to plaster the walls at Çatalhöyük.¹⁸ Thin section examination of the white, calcareous silty clay revealed sediments composed of up to 95% pure calcium and magnesium carbonates, similar to soft lime deposits from the region. To this day, villagers mix these deposits with water to plaster floors and walls.

Houses were constructed on a rectangular plan, each consisting of approximately twenty-five square meters. Interior spaces generally consisted of one main large room and, in some cases, additional smaller rooms with an entrance or opening raised off the floor plane. Entrance to each house was gained through a hole in the roof accessed by a wooden ladder placed against the south wall of the main room. This opening also provided ventilation for the hearth and oven below. Roofs consisting of a layer of reeds covered with a thick layer of mud were staggered to allow each building access to light. Individual residential units, as opposed to communal living spaces, are as yet difficult to

¹⁷ Results of thin section examination described in Wendy Matthews, Charles French, Timothy Lawrence and David Cutler, "Multiple Surfaces: the Micromorphology," in *On the Surface: Çatalhöyük 1993-95*, Ian Hodder, ed. (Cambridge: McDonald Institute for Archaeological Research; London: British Institute of Archaeology at Ankara, 1996), 304.

¹⁸ Wendy Matthews, Charles French, Timothy Lawrence and David Cutler, "Multiple Surfaces: the Micromorphology," in *On the Surface: Çatalhöyük 1993-95*, Ian Hodder, ed. (Cambridge: McDonald Institute for Archaeological Research; London: British Institute of Archaeology at Ankara, 1996), 304.

discern due to the lack of doorways that would suggest adjoining rooms.¹⁹ Party walls were rare, internal spaces physically defined by double or triple walls, which may have served to support the roofing, to act as insulation, or perhaps to emphasize boundaries of personal space.

The proximity of buildings, ranging from 2-35 cm apart, did not allow room for streets or alleys. Therefore, communication between neighbors was carried out at roof level. Furniture consisted mainly of built in platforms, benches, hearths, and ovens. Most rooms contained bins for grains or storage. The outer wall of the settlement, as uncovered by Mellaart's team, was void of any opening.²⁰

Analysis of occupation debris indicates a settlement consisting of residences and open spaces, the latter used primarily for rubbish disposal and sanitation. Mellaart made a distinction in building use between dwellings and shrines based on the richness of decoration and distribution of the remains found in each. However, sufficient evidence has not been found to differentiate the sacred from the secular within the settlement.²¹ Activities associated with both domestic and burial practices are often evidenced within

¹⁹ The discovery of what may be a door between houses indicates that more than one form of access may have existed between some houses. Ian Hodder, "Conclusions," in *On the Surface: Çatalhöyük 1993-95*, Ian Hodder, ed. (Cambridge: McDonald Institute for Archaeological Research; London: British Institute of Archaeology at Ankara, 1996), 363.

²⁰ James Mellaart, "Çatal Hüyük in Anatolia: Excavations which Revolutionize the History of the Earliest Civilizations. Part II-Shrines and Buildings," in *The Illustrated London News: Archaeological Section No. 2122* (February 2, 1963) 160.

²¹ The buildings classified as shrines do not differ in structure, size, or internal organization from the houses and, for the most part, are intermingled with them throughout the settlement. Also no distinction was found to exist in the construction materials of either building type. Although both contained below-platform burials, Mellaart believed that "shrines" housed the monumental reliefs and wall paintings. All buildings contain hearths, ovens, and storerooms and were kept exceptionally clean. Ian Hodder, "Contextual

the same building. The presence of red ochre paint on platforms above human skeletal remains as well as in occupation and fire installation deposits, indicate ritual/burial activity throughout the settlement.²² Because many buildings display evidence of multiple use and/or changes in use all of the buildings are now considered dwellings.

Often what were once buildings became open spaces and vice versa. Variations within the continuity of building layout have been detected between buildings.

Occupation levels in which evidence of multi-use and transitions exist, show that changes have occurred over the long term. Elaborate buildings appear to have been reconstructed on the site of other elaborate buildings. And, artistic motifs have been observed to survive from one level to the next. Surface examinations indicate the controlled use of fire within architectural spaces, perhaps to signify the end of use of a space.

At present, the settlement is understood as an agglomeration of architectural spaces ranging in elaboration from simple or decorative to symbolically complex.²³ No evidence has yet indicated the existence of large-scale public buildings. The distribution of evidence for crop processing, animal tending, and obsidian manufacture amongst domestic spaces combined with the simplicity of the two part plan, indicate that

Archaeology: An Interpretation of Çatal Hüyük and a Discussion of the Origins of Agriculture" in *Institute of Archaeology Golden Jubilee Bulletin Number 24* (London: Institute of Archaeology, 1987) 44.

²² Wendy Matthews, Charles French, Timothy Lawrence and David Cutler, "Multiple Surfaces: the Micromorphology," in *On the Surface: Çatalhöyük 1993-95*, Ian Hodder, ed. (Cambridge: McDonald Institute for Archaeological Research; London: British Institute of Archaeology at Ankara, 1996), 317.

²³ Jonathon Last, "Surface Pottery at Çatalhöyük," in *On the Surface: Çatalhöyük 1993-95*, Ian Hodder, ed. (Cambridge: McDonald Institute for Archaeological Research; London: British Institute of Archaeology at Ankara, 1996), 164.

Çatalhöyük functioned as a village rather than as an urban center.²⁴ Nonetheless, the elaborate wall paintings, painted plaster reliefs, and burial customs occurring at Çatalhöyük suggest that this population lived in a very complex symbolic culture that appears to have revolved around continuity and ancestor worship.²⁵

The Population

The extensive physical evidence discovered at Çatalhöyük has dramatically altered traditional views of prehistoric Anatolia and the Near East in general. Its significance is twofold: the physical evidence provides information on the culture and social systems of a Neolithic society; and in turn, we have gained a heightened understanding of human resourcefulness and adaptability. Here it was discovered, a civilization with sophisticated artistic ability and complex religious beliefs had existed. The wall paintings, plaster reliefs and sculpture, as well as evidence of weaving, woodwork, metallurgy and obsidian working demonstrate an advanced level of achievement.

The population of Çatalhöyük probably survived on an economy of irrigation agriculture, animal husbandry, hunting, and domestic industry.²⁶ Evidence of the domestication of dogs and cattle was produced during excavation of Mellaart's Level XII,

²⁴ Roger Matthews in *On the Surface: Çatalhöyük 1993-95*, 86-87.

²⁵ Ian Hodder, "Conclusions," in *On the Surface: Çatalhöyük 1993-95*, Ian Hodder, ed. (Cambridge: McDonald Institute for Archaeological Research; London: British Institute of Archaeology at Ankara, 1996), 366.

²⁶ Documentary evidence of a simple irrigation system was noted in one of the fragmentary paintings excavated by Mellaart. James Mellaart, *The Goddess from Anatolia* (West Germany: Udo Hirsch, 1989) Vol. 2, 38.

representing a pre-seventh millennia B.C. settlement.²⁷ The importance of cattle to the population of the settlement both as a source of food and transport, is seen in its continuous pictorial representation, in both naturalistic and abstract forms, in material culture remains. The aurochs was represented in wall paintings found throughout the settlement levels, as were bucrania, which were often plastered and incorporated into the architecture. Despite the domestication of plants and animals, hunting was popular for sustenance and sport, and was represented in wall paintings and in the ornament of weapons and arrowheads in the burials of men.

The population had a wide range of locally available foodstuffs including game, fish, fruit, nuts, vegetables and dairy products. Although domesticated cereals have been discovered, dental microwear studies conducted on human skeletal remains and a lack of grinding artifacts indicate that cereal was probably not a staple of the diet. Evidence indicates that the people ate mainly tubers and pulses.²⁸ Although occupation deposits rarely reveal fish bones, wall paintings discovered by Mellaart depict nude women with nets and fish. Further, the practice of food and beverage storage, which was new to the sedentary culture, probably led to the production of beer and wine through the natural fermentation process.

Archaeological studies have shown that the population at Çatalhöyük was a mix of Euraficans, 59%, descended from an Upper Paleolithic type, Proto-Mediterraneans,

²⁷ James Mellaart, *The Neolithic of the Near East* (London: Thames and Hudson, Ltd., 1975) 98.

²⁸ Theya Molleson and Peter Andrews, "Trace Element Analyses of Bones and Teeth from Çatalhöyük," in *On the Surface: Çatalhöyük 1993-95*, Ian Hodder, ed. (Cambridge: McDonald Institute for Archaeological Research; London: British Institute of Archaeology at Ankara, 1996), 265.

17%, and brachycephalic Alpines, 24%. The average life expectancy for both men and women was approximately thirty years and the maximum population at any given time would probably have been approximately 5-6,000.²⁹

The site is rich with material evidence of the culture. The level of skill of a portion of the population is attested to by the quality and complexity of the wall paintings. The stationary culture, made possible by an economy based on agriculture and the domestication of animals, allowed for the development of specialized craftsmanship. Production areas or workshops have not been identified. Although only finished products have been found in very clean buildings, it is unlikely that so wide an array of finished products were imported.³⁰ It is believed that production areas within the settlement have yet to be excavated.³¹

Wall Paintings

The excavated wall paintings at Çatalhöyük are some of the earliest yet found on man-made walls. As many as 80 two-part sequences of ground and finish plaster layers, each measuring 0.5mm or less, were revealed in the examination of representative earthen plaster and mudbrick samples sent from Çatalhöyük. Paintings, most often executed on the dense white finish plasters, were microscopically observed in cross-section examination between many of the super-imposed sequences. Several unpainted plaster layers often separate them. Laboratory and *in situ* examination of the plasters reveal

²⁹ Ibid, 99.

³⁰ Well-made objects in obsidian, imported flint, stone, metal, beads, textiles, and pottery, wooden statues and vessels have all been found on site.

³¹ James Mellaart, *Goddess from Anatolia*, Vol. 2 (West Germany: Udo Hirsch, 1989) 7.

several types of deterioration including: the loss of cohesive strength within discreet layers and adhesive strength between individual layers of the plaster and mural paintings, macro-biological growth, and salt migration. Causes of deterioration may be linked to drastic environmental changes brought on by excavation.

The degree of preservation of newly excavated wall paintings suggests that they were usually painted over while still in good condition.³² During the 1960s, layers of plain plaster were often manually removed in order to reveal paintings on preceding layers. Removal at this time was a slow process, conducted with small dental knives and scalpels to remove the undecorated plaster layer by layer from the painting. This type of technique requires enormous care to prevent damage to the painted surface.

Many of the wall paintings uncovered in the 1960s were removed to a conservation laboratory. Detachments were carried out in two ways, the block method, in which the painting was removed along with a portion of the mud brick wall (*stacco a massello*); and the peeling method, in which the surface of the painting was coated with an adhesive and a linen facing, permitted to dry, and peeled along with a small amount of plaster away from the mudbrick wall (*strappo*).

Both the dry climate, and the retention of substantial portions of the architecture may explain the outstanding state of preservation of many of the wall paintings directly after excavation. Newly exposed paintings however, begin to degrade after just a short

³² Paintings are rarely discovered directly on the surface of a wall during excavation. Discovery usually occurs due to losses within overlying plaster layers.

time in the open air, and are often found detached from the walls, fragmented and buried in rubble.

Pigments were derived mainly from minerals, including among others, azurite, cinnabar, malachite, and galena, all of which occur naturally on the Anatolian Plateau.³³ Most often, the paintings were executed on a cream or white ground, the bristle marks of a fine brush sometimes visible. Generally, paintings were confined to a single wall panel, although exceptions occur in which a scene continues from one wall around the corner onto the next.

The preliterate society at Çatalhöyük probably used imagery and symbolism as a means of communication to formulate and illustrate belief systems, history, religion and ritual. Although some of the paintings may be purely decorative, the subject matter of others strongly indicates religious and philosophical beliefs. Repetition of designs and their continuous use throughout the duration of the settlement indicate that these were established forms of expression. If so, functional representations would not necessarily have been realistic. Images may not represent daily situations at all, but may instead refer to myth, legend, or history. Wall paintings must be observed in a context encompassing all material culture remains, if they are to aid in the interpretive process.

A Society in Transition

As stated above, the settlement at Çatalhöyük represents the transition of a society from an economy based on hunting and gathering, the Paleolithic, to one based on the

³³ James Mellaart, *Catal Hüyük: a Neolithic Town in Anatolia*, (London: Thames and Hudson, 1967) 131

domestication of plants and animals, the Neolithic. It would not be surprising then that as elements of the lifestyles carry over, so too would the focus of imagery and symbolism.

The oldest mural paintings discovered date to the Paleolithic period; the most famous of which are located in France and Spain. The material culture of the Paleolithic people reflected their nomadic lifestyle and most often took the form of movable objects. Monumental cave paintings were the exception. Placement and style of these Paleolithic paintings, located sometimes deep within caves' interiors, indicate that they may have served ritual purposes. Their imagery consisted mainly of wild animals and game, which are believed to represent the culture's main source of food; female statuettes; and geometric motifs.³⁴

Paintings at Çatalhöyük share a similar subject matter. Animal scenes are common and may illustrate hunting scenes, although none depict an actual kill. Human figures appear to dance around animals, such as the deer and the aurochs.

The two periods also share a color palette. Artists of both the Paleolithic and the Neolithic made great use of red and black paints. So often in fact, that it is difficult not to imbue them with symbolic meaning, usually interpreted as life and death. This interpretation is supported by the red ochre burials found in the Paleolithic, later at Çatalhöyük and at other settlements throughout the world. Traces of red paint were discovered on many of the architectural elements at Çatalhöyük.

³⁴ Early examples also exist at Beldibi, Öküzlü 'In, Kara In, Kürtün and the Palanlı caves as cited in James Mellaart, *The Goddess from Anatolia* (West Germany: Udo Hirsch, 1989) Vol. 2, 3.

Symbols or motifs, such as the repetition of triangles, circles, “swastikas,” and hands and opposing triangles, alternating in color between red and black with white dots, forming positive and negative bands or combined in groups of four creating a rhomb, can be seen in both Paleolithic cave paintings and in the mural paintings of Çatalhöyük..

Another motif common to both periods may be found in the depiction of women. Sexual characteristics are emphasized in the Paleolithic art of Western Europe and a number of Near Eastern settlements of a much later date. The Venus figures of the Paleolithic are believed by Mellaart to have evolved at Çatalhöyük into a figure he called the “Goddess.” He wrote repeatedly of a “goddess” image in painting, relief, and figurine form, using the term as a blanket category for the majority of the discovered female and questionably female images. This figure is shown in many variations and compositions: in reciprocal or cross forms, connected or in mirror image, natural, and abstract. Sometimes naturalistic representations are combined with the abstract and include animals. Current scholarship rejects many of these theories due to the lack of supporting evidence.³⁵

The figures have been perceived in a number of ways. At times, they appear to be pregnant, or to be giving birth to humans, wild animals or birds. Sometimes they seem to be twinned or joined to a mate. Some of the excavated murals very clearly depict female figures with nets, fishing.

³⁵ For further discussion, see Ian Hodder, “Contextual Archaeology: An Interpretation of Çatal Hüyük and a Discussion of the Origins of the Origins of Agriculture” in *Institute of Archaeology Golden Jubilee Bulletin Number 24* (London: Institute of Archaeology, 1987) 45. The author finds no indication of clearly female

Women were also shown with wild animals. The depiction of a female figure with two vultures is common in Anatolia. The union of a symbol of fertility and one so closely associated with death and rebirth indicates a powerful symbolism. It has been suggested that the relationships between men and women, domestic and wild, and life and death have been worked out in the imagery, the architecture, and even the city plan of Çatalhöyük.³⁶ The connection between women, as the givers of life, and predators, or dangerous animals, implies that women may have had a dual symbolic role relating to both death and renewal.³⁷ They appear at least symbolically, to have had a role in all aspects of the cycles of human and animal life.³⁸ The relatively brief life expectancy of the population of Çatalhöyük, approximately thirty years, gives credence to the belief that the symbolism refers predominantly to fertility and reproduction.

The subject of death appears to be a recurring theme amongst the wall paintings and reliefs. Birds were often depicted in association with headless human beings. These images are believed to represent the excarnation process. If this is true, the vultures perform part of a burial rite by stripping the flesh from the bones of the dead before their final burial and ultimate rebirth. In some cases, vultures have human feet, indicating human participation in the process.

characteristics on the relief figures described by Mellaart as pregnant goddesses giving birth, sometimes to humans, others to animals.

³⁶ Ian Hodder, "Contextual Archaeology: An Interpretation of Catalhöyük and a Discussion of the Origins of the Origins of Agriculture" in *Institute of Archaeology Golden Jubilee Bulletin Number 24* (London: Institute of Archaeology, 1987).

³⁷ Ian Hodder, "Conclusions," in *On the Surface: Çatalhöyük 1993-95*, Ian Hodder, ed. (Cambridge: McDonald Institute for Archaeological Research; London: British Institute of Archaeology at Ankara, 1996), 365.

Imagery at Çatalhöyük is sometimes expressed in positive and negative images that emphasize the relationship between the figure and the background. This interplay is deliberate and what at first appears to be an abstract pattern may in fact be recognizable figures.³⁹ The relationship between positive and negative space undoubtedly had symbolic meaning, each side of equal importance.

Thus, the concerns of these people, as expressed through their illustrations, appear to be fertility, death, and rebirth. These are universal concepts, represented materially in cultures all over the world.

Continuity

Striking examples of wild animal imagery support the idea of a continuous belief system. A pair of modeled leopards coated with numerous campaigns of painted plaster exhibit only slightly evolving designs. The aurochs is found continuously in the imagery of Çatalhöyük in the form of bucrania, plastered and painted and set into benches or hung on walls and in wall paintings. Portrayed most often as a sexless bull, the symbol has been equated with male fertility as well as domestication of the wild.⁴⁰ Whatever the

³⁸ Walter A. Fairservis, Jr., *The Threshold of Civilization, An Experiment in Prehistory* (New York: Charles Scribner's Sons, 1975), 155.

³⁹ James Mellaart *The Goddess of Anatolia* (West Germany: Udo Hirsch, 1989) Vol. 2, 28.

⁴⁰ The equation of bulls with male virility is however, a western perception not necessarily borne out in this context. Naomi Hamilton, "Figurines, Clay Balls, Small Finds and Burials," in *On the Surface: Çatalhöyük 1993-95*, Ian Hodder, ed. (Cambridge: McDonald Institute for Archaeological Research; London: British Institute of Archaeology at Ankara, 1996), 252.

interpretation, the symbolic significance of this image is witnessed by its use in other cultures.⁴¹

Mellaart noted the similarity between excavated wall paintings and much later kilim patterns. In his article, “The Leopard Shrines of Chatal Huyuk,” he described a building “decorated with several super-imposed layers of textile pattern, imitating kilims.”⁴² It is now believed that the striking similarities between Neolithic wall paintings and designs found centuries, even millennia later in Anatolian kilim design, are inherited from Neolithic symbolism.⁴³

Çatalhöyük is believed to be the only ancient site as yet to exhibit such a wide variety of both naturalistic and abstract imagery.⁴⁴ Mellaart divided the wall paintings and reliefs into the following categories:

Monochromatic plaster panels usually painted with some form of red,

- Geometric patterns in both monochrome and polychrome, sometimes repetitive or mirror image, either rectilinear or curvilinear,
- Symbolic images including circles, quatrefoils, crenellations, stars, swastikas, and triangles,

⁴¹ Bucrania was used as an architectural element at an earlier site, Mureybet Ia in northern Syria, dating from between 10,000-7500 BC.

⁴² James Mellaart, “The Leopard Shrines of Chatal Huyuk,” in *The Illustrated London News: Archaeological Section* No. 2246, June 4, 1966) 25.

⁴³ James Mellaart, Udo Hirsch, and Belkis Balpinar conducted an extensive study of the relationship between kilim designs and the imagery found in the wall paintings at Çatalhöyük. Although specific belief systems cannot be deciphered, the discovery of similarities in the design or symbolism of people separated by time or space may prompt continued study of the paths of communication, knowledge, and trade which may not otherwise have been considered.

⁴⁴ James Mellaart, *The Goddess from Anatolia* (West Germany: Udo Hirsch, 1989) Vol.3, 38.

- Panels covered with handprints or silhouettes, usually with five fingers, or hands framing panels with geometric or naturalistic designs,
- Naturalistic images depicting human figures, bulls, birds, vultures, leopards, deer, ibexes, bees, found either by themselves or grouped into elaborate scenes, such as hunts, fishing, or funerary rites; also scenes depicting bears, boars, and bulls surrounded by humans, some of whom wear leopard skins, and
- Images depicting landscapes such as a tree ripe with fruit surrounded by ibexes; the settlement with a yurt-like structure and the volcano Hasan Dağ in the background.⁴⁵

Through artistic imagery, viewed in a social and cultural context across time and space, we have the potential to increase our general understanding of a past civilization. Preservation and presentation of these paintings may serve to enhance our understanding of the lifestyle of Çatalhöyük's inhabitants. With this in mind, the conservation, analysis, and interpretation of wall paintings at Çatalhöyük should include the context of the painting within the room, the building, the site, the region, and finally, within the Near East.⁴⁶

⁴⁵ James Mellaart, *Çatal Hüyük: A Neolithic Town in Anatolia* (London: Thames and Hudson, 1967) 132, 149.

⁴⁶ Dangers arise when Western perceptions influence the interpretation process. An example of this is described in the report, "Figurines, Clay Balls, Small Finds and Burials" by Naomi Hamilton in *On the Surface: Çatalhöyük 1993-95*, Ian Hodder, ed. (Cambridge: McDonald Institute for Archaeological Research; London: British Institute of Archaeology at Ankara, 1996), 226. She notes the risks involved in the interpretation of the large relief figures positioned atop animal heads as goddesses giving birth. This interpretation "fits beautifully with Western attitudes to virility and its appropriate symbols, but less well with evidence."

Conclusion

Comprehension of Near Eastern cultures may be improved through careful observation of the excavation at Çatalhöyük. Documentation of the wall paintings, architecture, pottery, figurines, and burials has been carried out and published by James Mellaart, Ian Todd, Ian Hodder, et al. Interpretations too, have been written and rewritten as methodologies and theories have changed.⁴⁷

Although the imagery found at Çatalhöyük can be tied to Paleolithic cave paintings, contemporary Near Eastern sites, and the Anatolian kilims design of the eighteenth through twentieth centuries, discussions about universal meanings must be conducted very carefully and critically. In a preliterate society, images and meaning may evolve or change without record. Wall paintings, relief plasters, and, to a lesser extent, figurines with dramatic imagery, indicate that a powerful symbolism was at work. References to the most basic of human concerns: fertility, death, and rebirth abound. An unbiased study and comparison of these paintings with those of other cultures and later periods may indicate a continuum of belief, transfer of knowledge, or the use of like symbolism to connote totally different ideas.

Accurate interpretation of archaeological sites requires that a sufficient amount of the settlement tract be excavated. Research from a wide range of disciplines may increase our potential to grasp the basic concepts of the lifestyle of an ancient people. Only with these concepts, and the contextual relationships between excavated remains,

⁴⁷ Mellaart reconsidered previous conclusions in a series, *The Goddess from Anatolia*, (James Mellaart, Udo Hirsch and Belkis Balpınar, 1989.) They explored continuity of material culture of the area from the wall paintings at Çatalhöyük to present day Anatolian kilim design.

can we begin to identify possible interpretations of any art. Even with such information, images representing religious or mythological beliefs may be interpreted as literal depictions of everyday life and vice versa. Images of animals and humans may represent themselves or deities. Basic knowledge of day to day life is helpful but is in no way a substitution for knowing the minds of the subjects under study.

Reopening the excavation at Çatalhöyük has underscored the need for collaboration between independent disciplines. Excavations may be better understood and interpreted by integrating information from many disciplines including, but not limited to, archaeology, conservation, art and architectural history, ethnoarchaeology, anthropology, botany, and folkloristics.

Significance of this excavation lies not simply in the light it has shed on the cultural aspects of a Neolithic society, but of equal importance, its potential to broaden our understanding of the adaptability of humans to their environments. At Çatalhöyük a society was, for the first time, dependent on the domestication of plants and animals rather than hunting and gathering.



Fig. 1. General map of Turkey. From Mellaart, James, Udo Hirsch, and Belkis Balpinar. *The Goddess from Anatolia*. West Germany: Udo Hirsch, 1989.

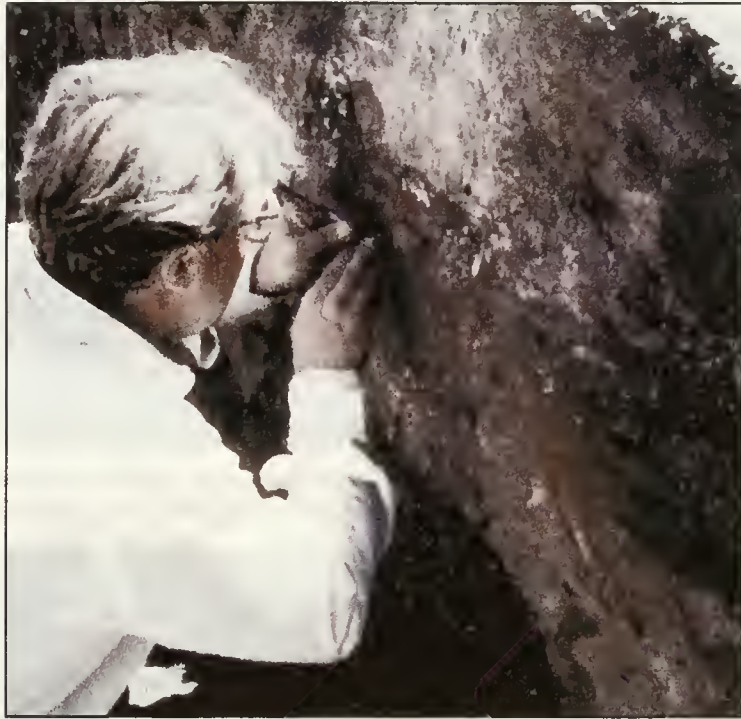


Fig. 2. James Mellaart working on excavated wall painting. From Mellaart, James, Udo Hirsch, and Belkis Balpinar. *The Goddess from Anatolia*. West Germany: Udo Hirsch, 1989.



Fig. 3. Painting from north wall of Shrine F.V/I showing bull surrounded by humans and other animals. From Mellaart, James, Udo Hirsch, and Belkis Balpinar. *The Goddess from Anatolia*. West Germany: Udo Hirsch, 1989.

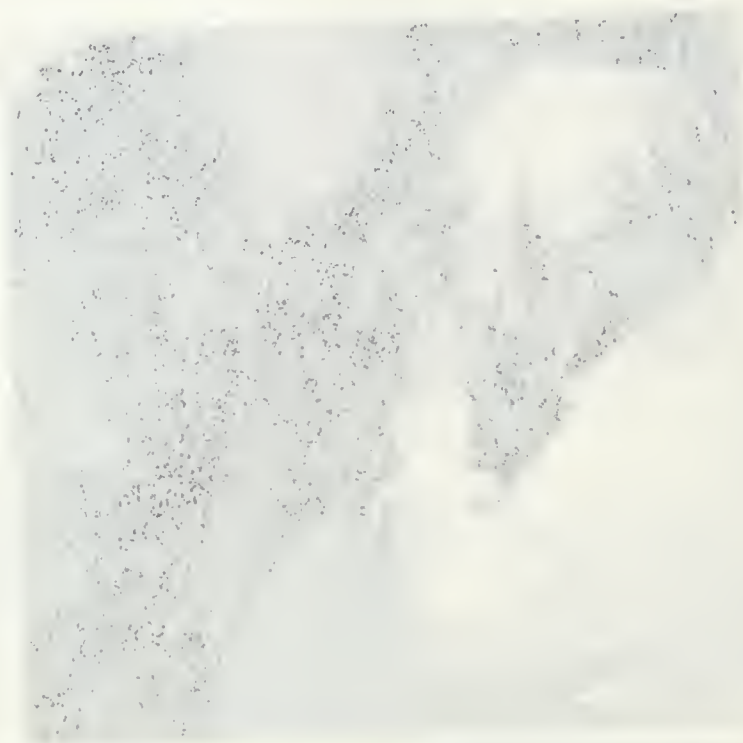




Fig. 4. Plaster relief and hand prints on red painted wall in Shrine E. VII/8. From Mellaart, James, Udo Hirsch, and Belkis Balpinar. *The Goddess from Anatolia*. West Germany: Udo Hirsch, 1989.



Fig. 5. Scale copy of painting from Shrine E. VIA/50. From Mellaart, James, Udo Hirsch, and Belkis Balpinar. *The Goddess from Anatolia*. West Germany: Udo Hirsch, 1989.



Fig. 6. Wall painting with alternating red and black triangles from Shrine E. VII/21. From Mellaart, James, Udo Hirsch, and Belkis Balpinar. *The Goddess from Anatolia*. West Germany: Udo Hirsch, 1989.



Fig. 7. Plaster relief of painted human figure from Shrine E. VII/21. From Mellaart, James, Udo Hirsch, and Belkis Balpinar. *The Goddess from Anatolia*. West Germany: Udo Hirsch, 1989.

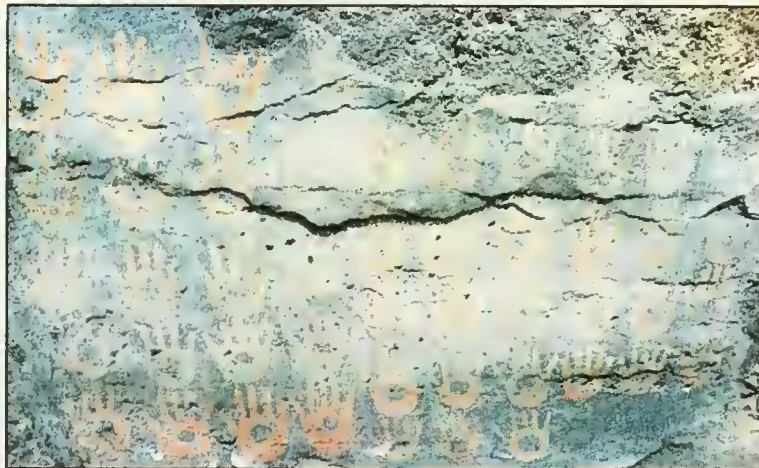


Fig. 8. Wall painting with hand prints from Shrine E. VIB/15. From Mellaart, James, Udo Hirsch, and Belkis Balpinar. *The Goddess from Anatolia*. West Germany: Udo Hirsch, 1989.



Fig. 9. Wall painting showing human figures in leopard skins from Shrine F. V/1. From Mellaart, James, Udo Hirsch, and Belkis Balpinar. *The Goddess from Anatolia*. West Germany: Udo Hirsch, 1989.

Chapter 2: Sample Development

The plasters and mural paintings at Çatalhöyük are irreplaceable records of the art and culture of a Neolithic settlement. As with any similar research program, it was critical to prevent the permanent alteration or destruction of original material. For this research, facsimiles provided the most practical means by which to test treatments.⁴⁸ The creation of laboratory facsimiles required the characterization and replication in the laboratory, of the materials and conditions at the site.⁴⁹

To accurately produce a laboratory facsimile, it was necessary to understand the materials and technology used to construct Neolithic wall paintings. Several methods of examination informed sample formulation. Microscopic examination of representative earthen plaster and mudbrick samples reveals as many as eighty two-part sequences of ground and finish plaster layers, each measuring 0.5 millimeters or less. Paintings, most often executed on the dense white finish plasters, were observed in cross-section between many of the superimposed sequences. To replicate this stratigraphy, samples were made of multiple plaster and paint layers, similar in substance and character to those found at Çatalhöyük.

⁴⁸ Since the testing program required a large amount of sample, it was not possible to use original material.

⁴⁹ Variables such as paint composition, thickness of layers, presence of dirt or soot, and adhesion to the substrate were not strictly reproduced.

In order to reduce variables, the sample prototype was based exclusively on the characterization of the plaster and paint constituents and did not replicate conditions requiring accelerated aging, such as deterioration.⁵⁰ Other conditions occurring at the site, such as interlayer detachment and friability of the plaster surface, developed without inducement.

2.1 Existing Conditions:

Previous research indicates that the plaster was composed of materials locally available to the native population at Çatalhöyük.⁵¹ The mudbrick walls were often coated with up to 80 superimposed phases of two-part ground/finish plaster layers made from local marly soils.⁵² Microscopic examination revealed the presence of entire shells within the plaster layers suggesting that, although the technology to burn and slake lime existed, local soils were probably used without burning.⁵³

A preparatory layer ranging from 1-3 mm thick often coated the mudbrick surfaces as revealed by microscopic examination of Çatalhöyük plaster samples.⁵⁴ A light brown ground layer and a finer white finish coat were usually applied over the preparatory layer. The most common stratigraphy showed superimposed sequences

⁵⁰ Aging and deterioration may cause the disintegration of organic binding media resulting in the loss of cohesion of plaster and paint particles. Exposure to the elements, ultraviolet light, salt migration, and macro-biological growth serve to intensify molecular degradation.

⁵¹ In his earlier thesis, Evan Kopelson characterized the plaster using the following tests: bulk sample examination, cross section examination, thin section examination, scanning electron microscopy with x-ray spectroscopy, and wet chemical analysis of organic material content, soluble salt content, acid-soluble content, granulometry, and pH determination. Evan Kopelson, "Analysis and Consolidation of Architectural Plasters from Çatalhöyük, Turkey" (masters thesis, University of Pennsylvania, 1996).

⁵² See Introduction for detailed description of the mudbrick walls.

⁵³ Kopelson, 130-131.

⁵⁴ Microscopic examination was conducted on a Nikon SMZ-U stereoscope at 4x to 75x magnification.

consisting of ground layers, 0.5 mm or less in thickness, followed by finish layers as thin as 0.25 mm. Ground layers made from pale brown calcareous silty clay were usually thicker than the finish layers and often contained white inclusions. The finish layers may have been burnished, as they were often smooth and compacted and composed of finer whitish calcareous silty clay with very few medium or coarse particles. The extraordinary thinness of the strata suggests that the soils were probably sieved and mixed with enough water to form a substance similar in consistency to a limewash or slurry.

Previous analysis of these plasters indicate that they generally consist of fine calcite particles, quartz, feldspars, and unburned shell fragments bound in a clay matrix.⁵⁵ Although it was not possible to identify the clay precisely, geological studies corroborate other evidence that it is a local clay, montmorillonite, smectite.⁵⁶ It is remarkable that the same technology and materials were used for the entire sequence of wall plasters.

Compositional analyses, which focused on ground/finish sequences rather than individual layers, indicated the consistent use for all layers of a plaster mix of approximately 50% calcium carbonate, 40-47% clay and 3-10% sand. Thin section examination of the white plasters revealed a material made of up to 95% pure calcium and magnesium carbonates, a composition similar to the soft lime deposits currently found in the region.⁵⁷

⁵⁵ Kopelson, 130-131.

⁵⁶ Results of the x-ray diffraction analysis of the clay component of the plaster had not yet been obtained at the time this research was conducted.

⁵⁷ Wendy Matthews, Charles French, Timothy Lawrence and David Cutler, "Multiple Surfaces: the Micromorphology," in *On the surface: Çatalhöyük 1993-95*, Ian Hodder, ed. (Cambridge: McDonald Institute for Archaeological Research; London: British Institute of Archaeology at Ankara, 1996), 304-306.

Paints appear to have been composed of a limited number of pigments bound with an unknown medium. Red and black, two of the most commonly used colors in prehistoric painting are often interpreted as having symbolic powers, usually pertaining to life and death. Blacks were carbon-based. The red pigments were iron oxides and have been used since the Paleolithic Era. Of these, red ochre is known to have symbolic meaning in primitive societies to this day. Red painted imprints of hands discovered on walls at Çatalhöyük have also been observed at Upper Paleolithic and Native American archaeological sites.

2.2 Characterization of Original Materials

Analysis of pigments and organic binding media was based on three small plaster samples from the site. These multi-layered samples, obtained during the 1995 season, were inconsistent and showed three to fourteen layers, all without substrate. They did however, retain traces of painted plaster on their surfaces. One small sample labeled “sheena wall black” showed traces of black paint. Two other samples labeled “Ch 95 Mell 1014 5/9 8F” showed traces of light red and dark red paint, respectively. The samples were microscopically examined in cross section for stratigraphy. Pigments were characterized using microchemical spot tests and scanning electron microscopy with energy dispersive spectroscopy (SEM/EDS). Although the possibility of finding organic materials was improbable, samples were studied for the presence of organic binding

medium. Staining techniques, both simple direct reactive staining; and fluorescence staining, showed no indication of organic materials.⁵⁸

Based on these results, three original sample types were selected as models for laboratory facsimiles. These samples, ranging from (1 inch)³ to (2 inches)³ were chosen because they retained painted surfaces, possibly mural painting surfaces; and because they consisted of multiple super-imposed ground/finish layers, most representative of the site.

⁵⁸ This aspect of research warrants additional study. It is recommended that a wide sampling of materials from various locations be analyzed with these and other methods for identification of organic materials.

The following table describes the samples.

Table 1

Sample	Description of Original Plaster Samples
RL (RL, RL1) "Ch 95 Mell 1014 5/9 8F"	Sample consists of approximately fourteen layers. Traces of light red paint appear on the surface.
RD (RD, RD1) "Ch 95 Mell 1014 5/9 8F"	Sample consists of approximately three plaster layers. Traces of dark red paint appear on the surface.
BL (BL, BL1) "Sheena wall black"	Sample consists of approximately seven plaster layers. Traces of black paint appear on surface

2.2.1 Analysis of Stratigraphies

Summary:

Microscope examination of cross sections provides a method for studying the general structure of mural paintings, including stratigraphies. This type of analysis, combined with surface examination and the identification of organic and inorganic components, facilitates an understanding of the techniques and materials used at different stages of execution. In addition, it may allow the investigator to observe the superimposition of earlier paintings, deterioration mechanisms, paint penetration, and discontinuities or transformations within the sequence.⁵⁹

Objective:

The aim was to microscopically characterize stratigraphies and pigment particles where apparent.

Methodology:

Unpolished cross sections were examined with a compound microscope at 100 x magnification in reflected visible light.⁶⁰ They were then photographed.⁶¹

Stratigraphic descriptions and accompanying photomicrographs of each sample follow.

⁵⁹ Paolo and Laura Mora and Paul Phillipot, *The Conservation of Wall Paintings* (London: Butterworths, 1984), 21-23.

⁶⁰ Embedded samples were not polished because the plaster was fragile, even after consolidation with Acryloid B67. The extensive loss of material caused by cross-sectioning and polishing dissolved surface material and muddled definition of stratigraphies.

⁶¹ Samples were photographed using the Nikon Optiphot polarized light microscope illuminated by fiber optics at 50X using Kodak Royal Gold 200 ASA film.

Observations:**Table 2**

Cross section examination: Sample RD1		
Layer	Type	Description
1	Finish plaster (?)	Densely compacted thick off-white homogeneous layer with black and brown inclusions; uneven distribution; voids; vertical cracking
2	Ground plaster	Densely compacted thick light brown heterogeneous layer with black, brown, and yellow inclusions; uneven distribution; voids; irregular cracking
3	Finish plaster	Loosely compacted thick white homogeneous layer; quartz inclusions; uneven distribution
4	Dark red paint layer	Bright orange red particles; heterogeneous in size and shape

Stratigraphic analysis of cross section of sample "Ch 95 Mell 1014 5/9 8F" (RD1) exhibiting traces of dark red paint on its outermost layer.

Sample RD1

Sample RD1 consists of approximately three layers of plaster and one layer of paint. The edges of Layers 2 and 3 are not well defined.⁶² Layers follow the typical light brown ground/fine white finish sequence although Layer 1 is darker than the finish coat directly underlying the paint layer. The ground layer is light brown with black, brown and yellow inclusions. The thick white finish layer is unevenly distributed. The paint layer on the surface of the sample is made up of bright red-orange pigment particles. There is no evidence of dirt or soot accumulation between the plaster layers. This may indicate frequent replastering or cleaning of the wall surface prior to new applications of plaster.

⁶² This may be due to the penetration of the BioPlastic embedding material into the sample.

Table 3

Cross section examination: Sample RL1		
Layer	Type	Description
1	Ground	Loosely compacted thick coarse light brown layer; brown and black inclusions
2	Finish	Compacted fine white homogeneous layer; discontinuous; barely visible
3	Ground	Loosely compacted thick coarse light brown layer; larger brown and black inclusions
4	Finish	Compacted fine white homogeneous layer; discontinuous; barely visible
5	Ground	Compacted light beige heterogeneous layer; brown, yellow, black inclusions
6	Finish	Compacted fine white homogeneous layer; very few black inclusions; discontinuous
7	Ground	Compacted thin light beige homogeneous layer; black inclusions; discontinuous
8	Finish	Compacted fine white homogeneous layer; very few black inclusions; discontinuous
9	Ground	Compacted thin light beige homogeneous layer; black inclusions; discontinuous
10	Finish	Compacted fine white homogeneous layer; very few black inclusions; discontinuous
11	Ground	Compacted thick light beige heterogeneous layer; brown, yellow, black inclusions; significant losses due to cross sectioning
12	Void	Discontinuous separation between layers
13	Ground	Loosely compacted thick coarse light brown layer; brown and black inclusions
14	Finish	Dense, discontinuous off-white finish layer; very few inclusions
15	Paint Layer	Deep red-orange and black particles; heterogeneous in size and shape

Stratigraphic analysis of cross section of sample "Ch 95 Mell 1014 5/9 8F" exhibiting traces of light red paint on its outermost layer.

Sample RL1

Sample RL1 consists of approximately thirteen plaster layers, one horizontal void indicating detachment, and one dark red paint layer. Micro cracking occurs vertically throughout the sample. Significant losses occurred during cross-sectioning preparation. The upper-most layers, 11-14, just below the paint layer are difficult to distinguish due to

damage and losses incurred during the sample cutting process. Layer 13, a loosely compacted light brown ground layer, is the most heterogeneous, with black, yellow, brown, and quartz inclusions of varying sizes. The finish layers 6, 8, and 10, are very white with very few inclusions. They are clearly delineated from the ground plasters. Layers 2 and 4 are extremely thin discontinuous finish plasters, barely visible even under magnification. The surface paint layer is made up of very fine deep red-orange and tiny black particles covered with a discontinuous layer of dirt.

Table 4

Cross section examination: Sample BL1		
Layer	Type	Description
1	Ground	Loosely compacted, thick light brown heterogeneous layer with black and brown inclusions; discontinuous; very large voids
2	Ground	Loosely compacted, thick light brown heterogeneous layer with black and brown inclusions; discontinuous; large voids
3	Ground	Loosely compacted thick light brown heterogeneous layer with black, brown, and yellow inclusions; discontinuous; large voids
4	Ground	Loosely compacted off-white heterogeneous layer with black, brown, and yellow inclusions; coarse particles; discontinuous; large voids
5	Ground	Compacted, thick light beige homogeneous plaster layer, finer grained; yellow and brown inclusions; black inclusions appear to be charcoal; discontinuous; large voids
6	Finish	Compacted, off-white homogeneous plaster layer, brown and black inclusions
7	Finish (?)	Compacted, off-white, homogeneous fine-particled plaster; very few black inclusions
8	Paint Layer	Very fine opaque black particles; heterogeneous in size and shape

Stratigraphic analysis of a cross section of the sample called "sheena wall black" exhibiting traces of red paint on its outermost layer.

Sample BL1:

Very little black pigment remained on Sample BL1. Cross section examination revealed seven plaster layers and one fine fragile black paint layer consisting of very fine opaque particles. Layers 6 and 7 are densely compacted homogeneous finish layers.

Cracking occurs vertically throughout the sample. Large voids and damage incurred in the sample cutting process, are visible mainly in layers 1-5, heterogeneous discontinuous ground layers that are almost indistinguishable from one another.

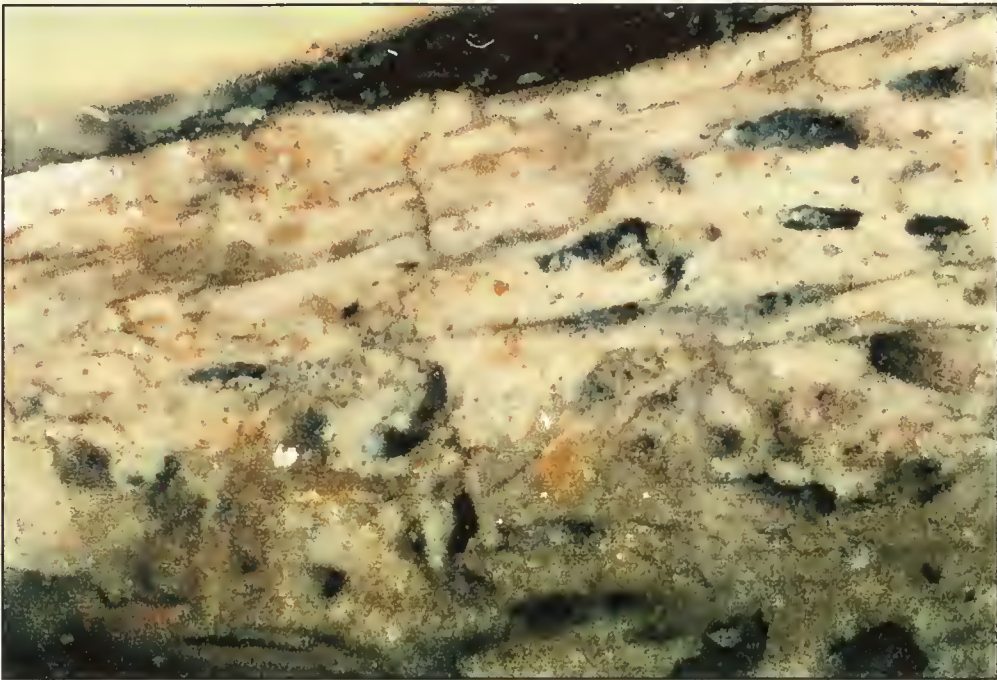


Fig. 10. Photomicrograph of cross section of "Sheena Wall Black" (BL1) sample showing traces of black paint on surface

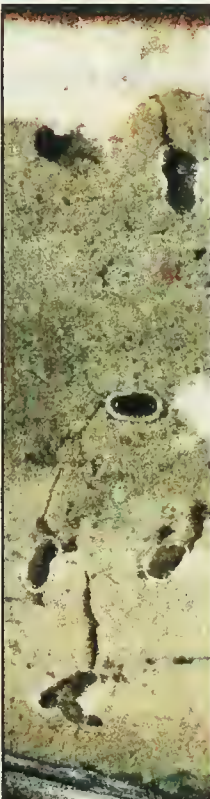


Fig. 11. Photomicrograph of a cross section "Ch 95 Mell 1014 5/9 8F" (RD1) sample showing traces of dark red paint on surface



Fig. 12. Photomicrograph of a cross section "Ch 95 Mell 1014 5/9 8F" sample showing traces of light red paint on surface (RL1)

2.2.2 Media Characterization

Summary:

The paints at Çatalhöyük appear to have been film-forming materials composed of pigment and binder. Pigmented layers applied over a white plaster finish coat exist as separate layers, apparently applied on dry plaster. Based on microscopical examination of samples in cross section; the layers range in thickness from 0.25 mm to 0.5 mm, and have weak cohesion and adhesion. Considering their appearance in cross-section and archaeological precedents, it is possible that these paint layers were bound with an organic binding medium.

Organic compounds have been used to strengthen colorants and adhere them to surfaces for thousands of years. These compounds, usually of human, animal, and vegetal origin, were used as vehicles or binders in paints, mortars and plasters to increase cohesive and adhesive properties.⁶³ Mediums and binders believed to have been used prehistorically for painting include water, urine, blood, eggs, and hot animal fat.⁶⁴

⁶³ The function of binding media is to bind the pigment particles into a workable mass and adhere them to the substrate. Historically, organic binders may be grouped into four main categories: lipids, oils and fats; proteins, such as, egg, casein and animal glues; glycerides or sugars; and empyreumatic materials, such as tars and bitumens.

⁶⁴ For further discussion, see R. J. Forbes, *Studies in Ancient Technology*, Vol. III (Netherlands: Brill, 1965) and L.J. Majewski, "The Conservation of Wall Paintings in Archaeological Excavations" *Preservation and Reproduction of Clay Tablets and The Conservation of Wall Paintings*. Colt Archaeological Institute (London: Bernard Quaritch Ltd.) 24-36.

Detection of organic materials of this age is unlikely due to the natural decomposition of organic binders.⁶⁵ Nonetheless, preliminary investigation for the presence of organic binding media was conducted using simple microscopical techniques.

Direct reactive staining is a simple laboratory method for characterizing the most commonly occurring binding media, notably glues, oils, egg, and gums. The presence of proteinaceous binding media such as gelatin, casein, and egg, may be detected by staining cross-sections with amido black, an acid stain that reacts with basic proteins. Staining with a solution of oil red may identify oils.

Ultra-violet fluorescence microscopy was selected as a preliminary method for examining cross-sectional samples, both to enhance the sample's stratigraphy and to indicate the presence of organic binding materials.⁶⁶ It was understood that the age of the sample and the limitations of the technique made it unlikely that this method would yield results.

⁶⁵ Disintegration or decomposition of a binding medium due to age or exposure to the elements occurs when the medium becomes powdery and falls away from the paint film. The resulting loss of cohesion and increased exposure of the pigment particles often results in the formation of a friable powdery surface. In addition to the decomposition processes that commonly occur with age, molecular degradation may be intensified by salt migration and exposure to ultraviolet light. For further information on the composition and properties of binding media, see Liliane Masschelein-Kleiner, *Ancient Binding Media, Varnishes and Adhesives* (Rome: ICCROM, 1985), and Adam Karpowicz, "Aging and Deterioration of Proteinaceous Media," *Studies in Conservation*, Volume 26, Number 4, November 1981, 153-160.

⁶⁶ Fluorescent materials emit visible light of longer wavelength when exposed to shorter wavelengths of ultra-violet and blue radiation. Dyes originally selected for biological applications may tag broad classes of organic compounds to produce secondary fluorescence. Based on research in the past two decades, a group of fluorescent dyes have been selected for characterizing organic binding materials for application in the fields of fine art and architectural conservation. Although useful for preliminary study, confirmation is often required. Additional research on this subject is recommended. More appropriate tests include: FTIR, GC-NIS, and HPLC. For further information, see Mortimer Abramowitz, *Fluorescence Microscopy. The Essentials, Volume 4* (United States: Olympus America, Inc., 1993); and Richard Wolbers and G. Landrey, "The use of direct reactive fluorescent dyes for the characterization of binding media in cross-sectional

Objective:

The aim of this study was to indicate the presence of surviving organic media in paint layers and plasters through direct reactive staining and fluorescent staining of cross-sectional samples.

Methodology:***Direct reactive staining:***

Two unpolished cross-section samples of each painted plaster, RL1, RL2, RD1, RD2, B11, B12, were analyzed for the possible presence of organic binding media. Based on the knowledge of ancient binding media, samples were tested for the presence of fatty materials, sugars, and proteins. The cross sections were first examined under low magnification in reflected light.⁶⁷

Fluorescence microscopy:

Two cross sections of each of the three painted plaster samples were studied using two different fluorescent dyes, triphenyl tetrazolium chloride (TTC), for the presence of

examinations,” in AIC Preprints, American Institute for Conservation 15th Annual Meeting, Vancouver, British Columbia, (Washington, D.C.:AIC, 1987) 168-202.

⁶⁷ The samples were not polished. A solution of amido black, AB1, composed of 1g of dye, 450ml glacial acetic acid, 450ml 0.1M aqueous sodium acetate, and 100ml glycerin, will stain the sample blue in the presence of egg yolk protein. The sample was immersed in the solution for five minutes and washed with 5% acetic acid. Another solution of amido black, AB3, composed of 1g dye, 900ml H₂O, and 100ml glycerin, will stain the sample blue in the presence of gelatin. The sample was immersed in the solution for five minutes and rinsed with 1% acetic acid. Oil red, composed of 6 ml of a stock solution: 0.5 g dye in 100ml isopropanol, and 4 ml H₂O, turns a sample pink in the presence of triglycerides and cholesterides. The sample was soaked for six minutes in pure isopropanol, and then immersed in the stain for an additional ten minutes. The sample was then washed three times, first with H₂O, then with 60% isopropanol, and finally with distilled H₂O again.

gums; and fluorescein isothiocyanate (FITC), for proteins such as animal glues.⁶⁸ They were observed using a Nikon Alphaphot 2 microscope with Episcopic Fluorescent Attachment EF-D.

Observations:

No appreciable results were obtained from either method. It is likely that any organic binding media still present within the samples has deteriorated.⁶⁹

⁶⁸ A 4% solution of triphenyl tetrazolium chloride was used to test for the presence of reducing sugars. This stain is sensitive to the action of reducing agents and in ultra-violet illumination will produce a dark reddish brown stain if carbohydrates are present. A 0.1% solution of fluorescein isothiocyanate was applied to test for the presence of proteins. A positive bright yellow stain will occur in the presence of egg, animal glues, or casein.

⁶⁹ The limitations of this technique are well noted. For example, it has been observed that porous samples with a low binder content can be penetrated by polyester resin embedding materials. Coated particles within the sample can inhibit the reaction of stains with binding media. For further information see, Michele Derrick, Luiz Souza, Tanya Kieslich, Henry Florsheim and Dusan Stulik, "Embedding Paint Cross Section Samples in Polyester Resins: Problems and Solutions," *Journal of the American Institute for Conservation*, Volume 33, No. 3 (Fall/Winter 1994): 227-228.

2.2.3 Pigment Identification

2.2.3.1 Microchemical spot testing

Summary:

Pigments may be inorganic (mineral) or organic (animal or vegetable) in origin. Mineral pigments are often derived from oxides, sulphides, carbonates, and sulphates found in the earth; organic pigments from animals, wood, fruits and plants. Prehistoric pigments were derived from clays and calcium carbonates for white; and earths, wood, and charcoal for black, brown, yellow, red and green.⁷⁰

To create laboratory facsimiles, it was critical to characterize the materials, technology, and structure of the original plasters and paints. For film forming paints, such as those believed to have been used at Çatalhöyük, both pigments and media must be considered. The presence of inorganic pigments was investigated because they would be more likely to survive and because they have been identified in paints in other prehistoric applications.

Inorganic pigments may be identified through a variety of methods. The most simple and accessible of these is microchemical spot testing.

⁷⁰ For further information, see Paolo and Laura Mora and Paul Philippot, *The Conservation of Wall Paintings* (London: Butterworths, 1984) 56-73; Rutherford J. Gettens and George L. Stout, *Painting Materials* (New York: Dover Publications, Inc., 1966); R. J. Forbes, *Studies in Ancient Technology Vol.III* (Netherlands: Brill, 1965) 210-264.

Objective:

The aim was to identify the pigments found on the wall paintings at Çatalhöyük using simple laboratory methods, notably microchemical spot testing and polarized light microscopy.⁷¹

Methodology:

Utilizing simple microchemical spot tests, pigments found on the surface layers of a selection of samples were analyzed.⁷²

Observations:

Two samples from the site were found to have traces of red pigment on their uppermost layers (Ch 95 Mell 1014 5/9 8F: RL2, RD2). One sample showed traces of

⁷¹ Previous paint analysis was reported on by Pamela French in a conservation report dating from 1968. Plaster and pigment samples were preliminarily analyzed using chemical spot tests. Potassium ferrocyanide was used to detect the presence of iron in a sample showing traces of red-brown paint on its surface. The same red-brown pigment was tested for the presence of blood. Positive results were obtained in both tests but further analysis was recommended. Pamela French, "Clay and Paint Samples: Preliminary Testing," (n.p, n.d.)

⁷² A tungsten needle was used to loosen and collect tiny fragments of the pigments at the edges of the paint layers. The resulting powdery samples were transferred to microscope slides. All the pigments were observed under the stereo microscope. A drop of concentrated HNO_3 was added to each red sample and then heated to evaporation on a hot plate to bring the particles into the ferric state. Confirmatory tests proceeded as follows. Additional samples were obtained and applied to slides as before. The pigment particles were again treated with single drops of nitric acid and heated to evaporation. A drop of HCl was then added to each sample and they were heated to evaporation to remove the HNO_3 . The resulting residues were mixed with a drop of water acidified with HCl . A fragment of potassium thiocyanate (KSCN) was then added to each sample. The presence of iron is indicated if a pink or red coloration is produced, its quantity, by the intensity of the color. The black pigment was tested for the presence of calcium and for phosphate. After heating the sample, the incombustible residue was dissolved in dilute HCl . $(\text{NH}_4)_2 \text{CO}_3$ was added to that to form a precipitate. The formation of a white precipitate is a positive indication of calcium carbonate. The residue was then tested for the presence of phosphate. Pigment particles were placed on filter paper, moistened with one drop of ammonium molybdate solution and warmed. A drop of benzidine solution was added and it was held over NH_3 . The formation of a brilliant blue color indicates the presence of phosphate. Dispersed samples were also prepared and analyzed by polarized light microscopy.

black paint on its surface (Sheena wall black). Microchemical spot testing indicated that both red pigments are iron oxides. The black pigment appears to be bone black.

2.2.3.2 Polarized Light Microscopy

Summary:

Pigments may be identified by determining their specific optical characteristics with the polarizing light microscope. Using a combination of plane and cross- polarized light, one may identify the following characteristics:

- Relative value of the index of refraction ($n > 1.66$; $n < 1.66$)
- Particle size, shape and color
- Isotropism / anisotropism
- Birefringence

Objective:

This study aims to confirm the results of microchemical spot testing for pigment identification.

Methodology:

Pigment samples were removed from the surface layers of a selection of samples with a tungsten needle. The pigment particles were microscopically separated from other particles and mounted on glass slides with Cargille Meltmount™ ($n 1.66$). Optical characteristics were observed at 100-400x with a Nikon Optiphot 2-Pol and recorded. Samples were compared with pigment slide and photomicrographic references. Representative samples were photographed. (See Figs. 13, 14, 15)

Table 5

Examination with Polarized Light Microscopy: Pigment particles	
Sample	Description
RL Ch 95 Mell 1014 5/9 8F	Plane polarized light: ▪ Minute crystals ▪ Heterogeneous in size and shape ▪ Average size was 1μ in diameter ▪ $n > 1.66$ ▪ Deep orange-red with black edges. Crossed polars: ▪ Birefringent spherulites ▪ Isotropic particles Result: The pigment is an iron oxide, most likely red ochre.
RD Ch 95 Mell 1014 5/9 8F	Plane polarized light: ▪ Minute crystals ▪ Heterogeneous in size and shape ▪ Average size was 1μ in diameter ▪ $n > 1.66$ ▪ Deep orange-red Crossed polars: ▪ Birefringent spherulites ▪ Isotropic particles Result: The pigment is an iron oxide, most likely red ochre.
BL Sheena wall black	Plane polarized light: ▪ Coarse, irregular particles ▪ Heterogeneous in size and shape ▪ Average size was 5μ in diameter ▪ $n \geq 1.66$ ▪ Translucent gray to opaque black Crossed polars: ▪ Some gray particles, characteristic of uncharred calcium phosphate Result: The pigment is bone black.

Observations:**RL1:**

Microchemical testing confirmed that the pigment in the red paint layer was an iron oxide. Microscopic examination using polarized light and comparison with known samples and photomicrographic references indicate that the pigment is red ochre, an earthy form of iron oxide composed mainly of clay and silica. Particles were heterogeneous in shape and composition and ranged from opaque to orange-red to transparent in transmitted light. The average size was 1μ in diameter. In plane polarized light, pigment particles were orange to deep orange-red with slightly black edges. Crossed polar examination showed isotropic particles and birefringent spherulites with refractive indices above 1.66. Examination using polarized light microscopy indicates that the pigment is probably a hydrated form of iron oxide, such as red ochre.

RD1:

Microchemical testing confirmed that this pigment is an iron oxide. Microscopic examination and comparison with known samples and photomicrographic references indicate that the pigment is red ochre. Particles were heterogeneous in shape with an average size of 1μ in diameter and ranged from opaque to orange-red to transparent in transmitted light. As in Sample RL1, particles ranged from orange to deep orange-red with slightly black edges in plane polarized light. Crossed polarization showed isotropic particles and birefringent spherulites with refractive indices above 1.66. Examination

using polarized light microscopy indicates a hydrated type of iron oxide, such as red ochre.

BL1:

Microscopic examination and comparison with known samples suggests that the pigment is bone black, a pigment made by charring animal bones. Particles were heterogeneous and coarse in shape and were translucent blackish-brown in transmitted light. The average size was 5μ in diameter. In plane polarized light, particles ranged from translucent gray to opaque black. In crossed polarized light, visible particles were gray, a characteristic of uncharred calcium phosphate. The refractive index varied from $n = 1.66$ to $n > 1.66$.

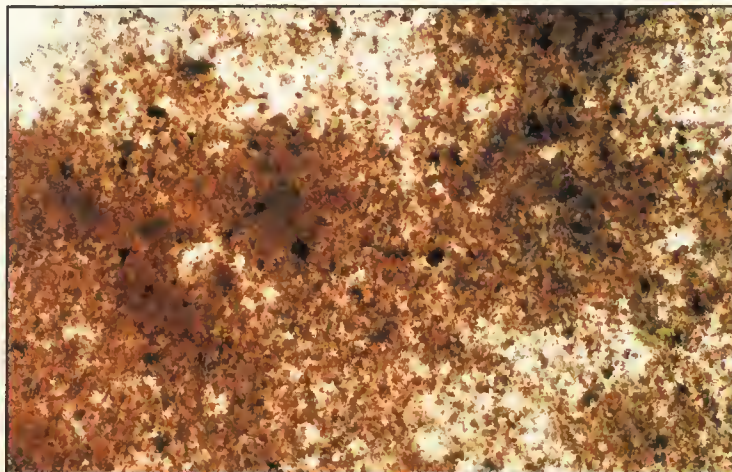


Fig. 13. "Ch 95 Mell 1014 5/9 8F" (RD1) iron oxide pigment particles

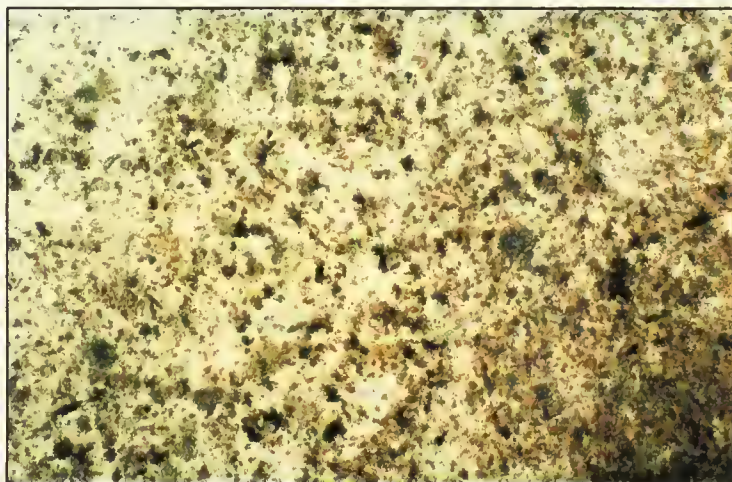


Fig. 14 "Ch 95 mell 1014 5/9 8F" (RL1) iron oxide pigment particles

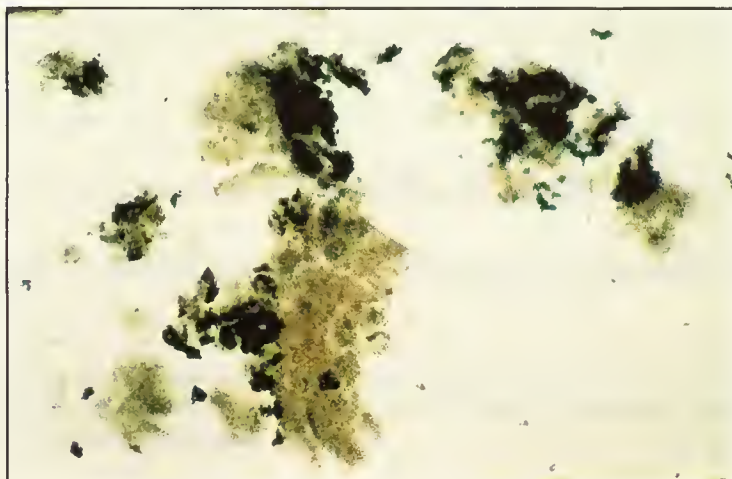


Fig. 15. "Sheena Wall Black" bone black pigment particles

2.2.3.3 Scanning Electron Microscopy with Energy Dispersive Spectroscopy (SEM/EDS)

Summary:

The scanning electron microscope may provide information on the morphology, particle size, shape, and texture of a specimen. It generates a three-dimensional micrograph by detecting the interactions of an electron beam on the surface of the sample. As an electron beam scans the surface of the specimen, an image is formed. Low points on the specimen emit low electron signals, thereby producing a corresponding dark point in the image. X-rays generated by this interaction are recorded and analyzed by a computer to assess elemental makeup. Composition may therefore be related to surface morphology.⁷³

The capabilities of magnification, ranging from 20,000 x to 100,000 x, and a depth of field of approximately 300 μ , provide a much greater level of examination than does optical microscopy. The energy dispersive x-ray analyzer may be used to produce an elemental spectrum and corresponding dot map illustrating the elemental composition of the sample.

Objective:

The aim of this examination was to confirm the identification of the red pigment previously indicated by microchemical spot tests and polarized light microscopy.

⁷³ For further information, see Dr. Sheldon Moll, "Scanning Electron Microscopy: A Versatile Analytical Tool," in *Technology and Conservation* (Spring 1976):24-28; Walter C. McCrone, John Gustav Delly and Samuel James Palenik, *The Particle Atlas*, 6 Volumes, ...

Methodology:

A cross-section of sample RD1 embedded in polyester/methacrylate resin, was coated with carbon to provide a conductive surface, and examined using the JEOL 6400 scanning electron microscope. The sample was observed at several magnifications. Energy dispersive x-ray spectra were produced to assess the relative quantity of the elemental components. X-ray dot maps show the occurrence of specific elements.⁷⁴

Observations:

Scanning electron microscopy with energy dispersive spectroscopy revealed a calcium-rich finish layer directly below the paint layer in sample RD1. The spectrum and x-ray dot maps representing the paint layer confirm that the red pigment has a high iron content. Silica is also present in this layer.⁷⁵ The pigment is probably hydrated iron oxide ($\text{Fe}_2\text{O}_3 \cdot n\text{H}_2\text{O}$). (See Figures 16, 17, 18)

Pigment identification, including microchemical spot testing, polarized light microscopy, and for one sample, scanning electron microscopy with energy dispersive spectroscopy, indicated that the pigments are iron oxide and bone black. This preliminary examination, combined with the results of earlier plaster characterization, served to inform the development of the laboratory facsimiles.⁷⁶

⁷⁴ SEM/EDS examination was carried out at the Laboratory for Research on the Structure of Matter at the University of Pennsylvania with the help of Rollin Lakis and Xue-Qin Wang.

⁷⁵ The presence of silica is not uncommon in iron oxide pigments. Some natural red oxide pigments contain as much as 70% iron oxides and 25% silica.

⁷⁶ These findings should be confirmed by additional pigment analysis on a wider selection of samples during this campaign. However, for the production of mural painting facsimiles, only those pigments identified in this study were used.

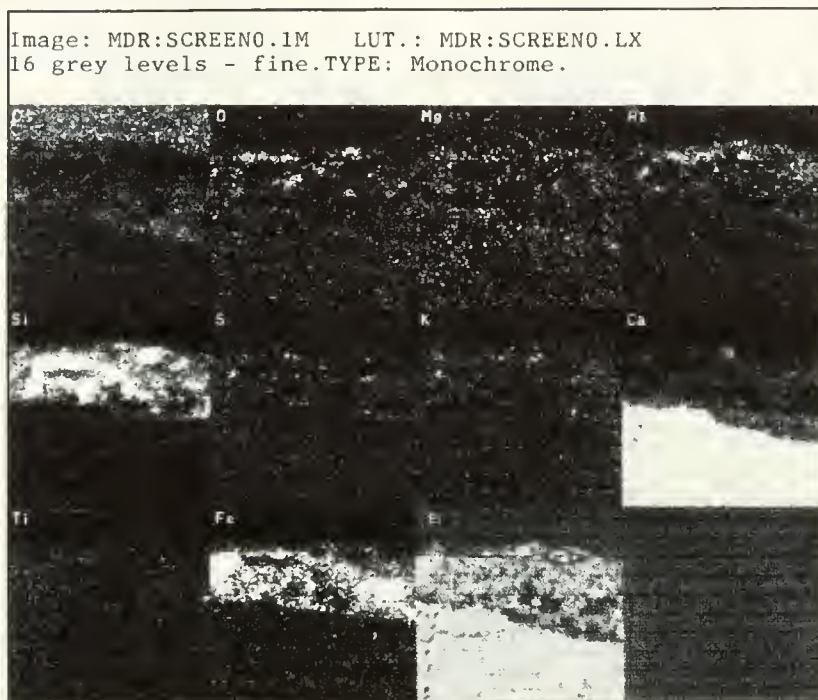


Fig. 16. X-ray dot map showing elemental composition of the red paint layer (Sample RD1)

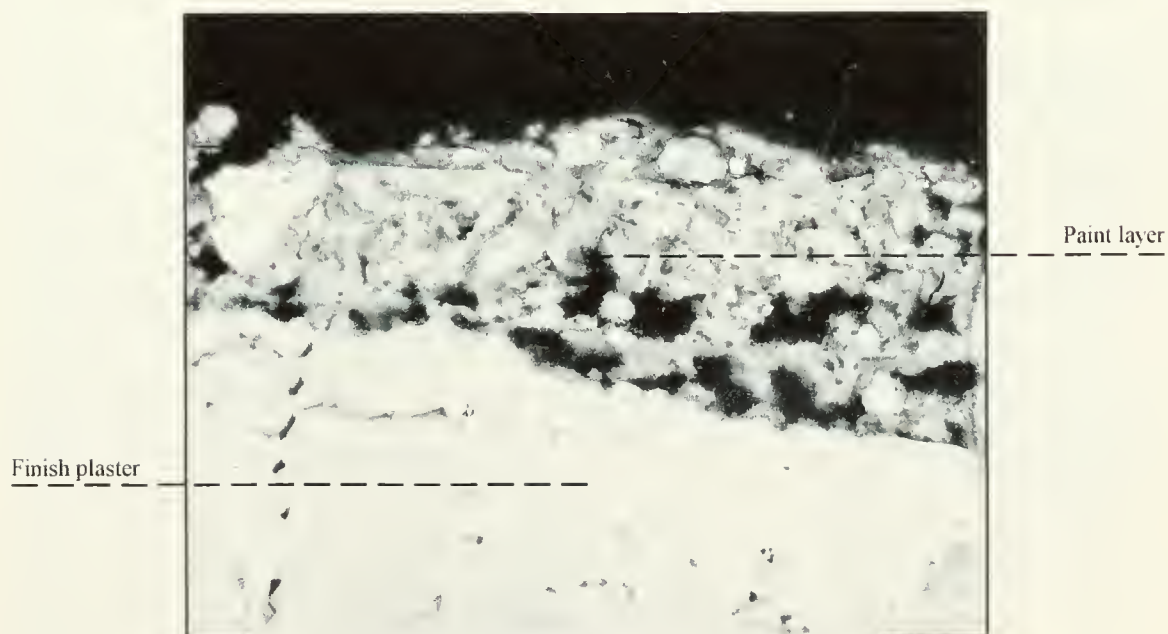


Fig. 17. Photomicrograph of sample RD1: 600 x

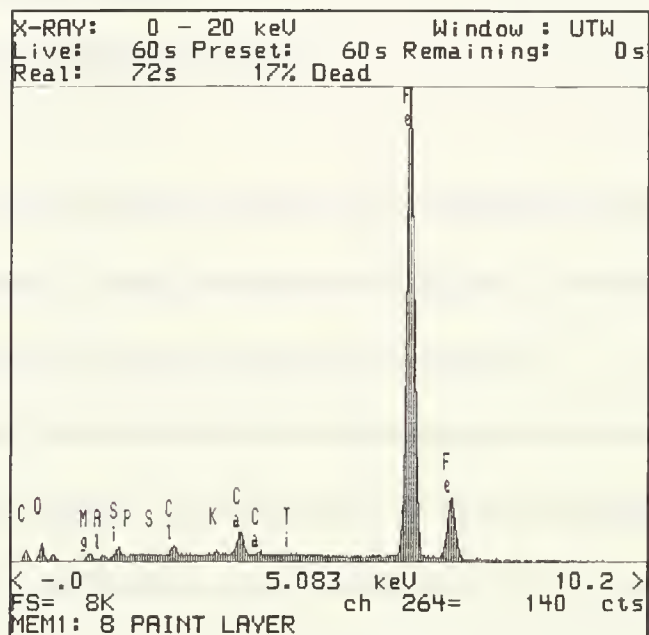


Fig. 18. EDS spectrum of the red paint layer (Sample RD1)

2.3 Creation of Sample Prototype

2.3.1 Materials for Laboratory Facsimiles

Summary:

In order to develop and test methods and materials for the detachment of the wall paintings at Çatalhöyük, a sample prototype was developed.⁷⁷ Extensive empirical testing of materials and techniques preceded its development.⁷⁸

All preliminary testing of materials and methods was carried out on samples made with plasters applied to gypsum board substrates. These were replaced by 12-by-12-inch terra cotta panels to more closely represent the character of the original mud brick substrate.

The basic formulation for the facsimile plasters was determined by nine characterization techniques completed in previous research, also at the Architectural

⁷⁷ Facsimiles were created at the University of Pennsylvania's Architectural Conservation Laboratory.

⁷⁸ Artist's whiting, a very finely divided powder derived from high calcium, or dolomitic limestone, marble, shell or chemically precipitated calcium carbonate was used in the initial testing program. Dry ingredients were mixed with enough water to form medium thick (yogurt-like) consistency. The plaster was brushed on in ½ millimeter thick layers to 24" gypsum board panels. The application of at least 50 layers of plaster to 20 of these panels resulted in severe cracking. The application of successive layers caused severe alligator cracking and extensive detachment of nearly all the plaster from the surface of the substrate. Attempts to simulate a three-millimeter thick preparatory coat resulted in extensive cracking. Trial plasters made from artist's whiting did not exhibit sufficient levels of cohesive or adhesive strength. Rabbit skin glue and gelatin were added to the mix in various concentrations but neither added sufficient strength to the plaster. Hydrated lime, a dry powder derived from the hydration of quicklime with enough H₂O to form a hydroxide, was substituted for artist's whiting. It imparted sufficient cohesive and adhesive strength to the plasters to allow for the required build-up of layers. Pre-testing consisted of numerous applications of the hydrated lime plaster mix using varying proportions. These were applied to untreated gypsum board panels and panels coated with Bin Primer, a pigmented shellac which prohibits the absorption of water into the substrate, theoretically diminishing the extent of cracking and detachment caused by loss of water from the plasters. The new plaster mix was successful, exhibiting minimal cracking. The difference in the performance between primed and unprimed panels was negligible, demonstrating that the primer was unnecessary. Further attempts to build up a thick preparatory layer using the hydrated lime/clay/sand plaster with additions of both rabbit skin glue and straw were still unsuccessful.

Conservation Laboratory of the University of Pennsylvania.⁷⁹ Sieving and wet gravimetric analysis determined particle size distribution, one of the major factors determining the character of plasters. Results of dry sieving are presented in Figure 21. Analysis of the plasters obtained from the site reveal a material composed of approximately 50-60% calcium carbonate, 40-47% clays and silts and 3-10% sand, a composition similar to that of the marly, clayey soils commonly found in the region. (See figures 19 and 20 for acid –soluble content results and particle size distribution information)

Objective:

The aim of this phase was to select materials and techniques for the creation of facsimile samples, similar in physical and chemical properties to those used in the construction of the Çatalhöyük mural paintings.

Calcium carbonate

Lime is the predominant material found in plasters and mortars of most primitive civilizations.⁸⁰ Hydrated lime served as the calcium carbonate component.

Sand

The function of sand in a plaster or mortar is to strengthen it by eliminating or decreasing the amount of shrinkage during drying. Finer binding particles fill the voids between the coarse grains of sand. The mixture becomes bound more tightly following

⁷⁹ For details, Kopelson, "Analysis and Consolidation of Architectural Plasters from Çatalhöyük, Turkey."

⁸⁰ Ralph Mayer, *The Artist's Handbook of Materials and Techniques* (New York: The Viking Press, 1970) 340.

shrinkage. Dry sieving indicated that the plasters at Çatalhöyük contain only a very small proportion of sand-sized particles, suggesting that the mixture was strengthened by the addition of organic binding components.⁸¹

Sand, purchased in bulk from a local building supplier, was sieved until an adequate amount of required grain sizes was obtained.

Clay

Geological studies indicate that smectite, a highly reactive montmorillonite clay, is the predominant clay in this region. It was difficult to obtain smectite for this study due to a lack of availability amongst United States suppliers. Therefore, bentonite, a montmorillonite clay with very similar characteristics, was substituted for use on laboratory facsimiles.⁸² Two forms of the clay, calcium bentonite and sodium bentonite were tested, and eventually used for the prototype mixtures.⁸³

The performance of the montmorillonite clay is critical to determining appropriate conservation treatments. The following section discusses the formation, characteristics, and properties of clays in order to explain their importance in the original plasters.

⁸¹ Traces and impressions of vegetal stabilizers in certain plaster components indicate plant matter as at least one of the organic materials used in the production of the plasters.

⁸² Bentonite clays were obtained from the Black Hills Bentonite Company in Mills, Wyoming.

⁸³ High sodium content bentonite, unlike the low sodium calcium bentonite, is film forming. It is highly reactive to water, and swells. The ability of sodium bentonite to adsorb a considerable quantity of water is due to the substantial internal surface area of clays in the montmorillonite family. Calcium montmorillonite may swell anywhere from 45%-145% in water. Although this is much more striking than the reaction between water and other clays, such as kaolinite, which increases only 20% in volume, it is still far less reactive than sodium montmorillonite, which swells from 1400%-1600% in water. Plasters made from sodium bentonite exhibited more shrinkage cracking in both ground and finish layers than those made from calcium bentonite. Failure to build up a thick preparatory coat with either of these clays resulted in the decision to omit the layer completely. The addition of organic materials, such as rabbit skin glue to several

2.3.1.1 Formation and characteristics of clays

Clays are essentially a weathering product of the disintegration and chemical decomposition of igneous rocks and some types of metamorphic rocks formed when silicate minerals interact with water by hydrogen exchange, a process based on the exchange of cations for hydrogen ions. Clays may form at temperatures ranging from 4°C to approximately 400°C in a time span ranging anywhere from hours to millions of years. Clay formation, the hydration of solids, occurs slowly at the earth's surface causing some of the material to alter at a different rate. This results in a soil composed of a combination of clay minerals formed in place, old partially altered minerals from the parent rock, and original minerals in an unaltered state.⁸⁴ Some clays, such as those obtained from the northern United States bentonite beds, were formed by the transportation and deposition of volcanic glass in an aqueous environment.⁸⁵

Beginning in the nineteenth century, clay minerals were defined by their crystal size, as fine-grained minerals whose particle diameters were less than 0.002mm or 2µm effective spherical diameter, a parameter based on resolution limitations of the petrographic microscope. The development of X-ray diffraction has allowed for the identification of different mineral species found in the <2µm-grain size. Characteristics of chemical reactivity in clays are determined by the internal chemical structure of the

of the samples did not significantly alter their properties. All of the samples exhibited extensive cracking and a near total lack of adherence to the substrate.

⁸⁴ Bruce Velde, "Composition and Mineralogy of Clay Minerals" in *Origin and Mineralogy of Clays* (Germany: Springer-Verlag Berlin Heidelberg, 1995) 5-7.

⁸⁵ Dorothy Carroll, *Clay Minerals: A Guide to Their X-ray Identification* (Colorado: The Geological Society of America, Inc., 1970) 1.

clay mineral. Physical characteristics may be attributed to size and specific crystal shape. Clays are both physically and chemically active. They attract water molecules, combining to form pastes, slurries, and suspensions, thereby altering their effective physical particle size. Clays may become chemical agents of transfer or transformation by taking ions or molecules onto their surfaces or into their internal structures.

Because of the small particle size of the material, the properties of clay minerals must be identified by the combination of analytical techniques such as x-ray diffraction, thermal stability, and infrared spectroscopy. Results of these tests provide a composite knowledge of the sample.

The small grain size of clay crystals imparts a large surface area in comparison to the volume of the particle. Because clay minerals are usually sheet-shaped, they have an even greater surface area than cubic or spherical minerals of the same grain size. Clay particles may be divided into three groups based on their shapes, flakes, laths, and needles.

The small mineral crystals that form clays attract polar water molecules to their surfaces through weak charge forces that eventually cover the crystals with several layers of weakly bonded water molecules. The aqueous solution is thickened, changing its viscosity. Combination of the mineral particles with water results in the formation of a plastic material. These sheet-like structures, sometimes called phyllosilicates or layer-lattice silicates, compact more densely than minerals of other shapes because they can be stacked tightly in parallel layers with large surfaces facing one another. The sheets are

made up of two structural units, a silicon-oxygen tetrahedron and an aluminum-oxygen-hydroxyl octahedron. These tetrahedral and octahedrally coordinated cations are bound to oxygens in a multi-layer structure in which the tetrahedra are linked to an octahedral sheet.

Swelling clays, such as smectites and bentonites, incorporate water molecules into their structures. The shape of the clay particle changes as water goes into and out of the structure making it particularly susceptible to changes in atmospheric conditions. A humid environment will tend to keep expansive clays constantly hydrated, while a dry atmosphere will keep it hydrated only occasionally. The volume of a clay particle can vary by as much as 95% depending on hydration.

Montmorillonites and Smectites

Smectites are clays with a 10-Å structure of low charge. This type of clay, known as a swelling or expanding clay, allows hydrated ions to be absorbed between the layers, thereby increasing interlayer distances. The presence of hydrated cations increases the normally 10Å unit to either 12.5Å for a single water layer state or to 15.2Å for a double water layer state. Soils containing large concentrations of smectites shrink extensively and crack upon drying.

The group name smectite includes both di- and trioctahedral molecular arrangements. Montmorillonite is a dioctahedral smectite. Montmorillonites are clay minerals that have water (H₂O) molecules rather than potassium cations (K⁺) or magnesium cations (Mg⁺²) ions tightly bonding their component layers. They have

alternately been called smectites (British usage), montmorillonoids, or montmorins. They are dioctahedral expanding aluminous minerals in which two tetrahedral layers are almost exclusively occupied by silicon. The charge imbalance is caused by divalent ion substitutions, iron (Fe) or magnesium (Mg), for the trivalent aluminum ions in the octahedral site. Dioctahedral smectite is formed by the reaction of rocks with solutions from neutral to alkaline pH. Sometimes dioctahedral smectite concentrates in a restricted space and forms a bentonite deposit. In such deposits, the smectite occurs as a monomineralic layer.

Bentonite clays

Bentonite clays are highly colloidal plastic montmorillonite clays that come from the Cretaceous beds near Fort Benton, Wyoming. They swell to several times their original volumes when placed in water and will form thixotropic gels even when the amount of bentonite is small. The term bentonite refers to clays formed by the alteration of volcanic ash *in situ*. It referred mainly to the Wyoming material until about 1940, when it came to connote clays that are highly plastic, colloidal, and swelling, without reference to a specific origin. They are most often composed of di-octahedral smectite clay minerals. The composition of the smectite varies from bentonite to bentonite. Variations may occur within the lattice structure of the smectite, in the occupation of the octahedral and tetrahedral layers, or in the nature of the exchangeable cations. Most bentonites carry a calcium cation (Ca^{++}) as the most prevalent ion. Fewer, most often from the Wyoming beds, carry a sodium cation (Na^{+}) as the prevalent ion. It appears that

in addition to the presence of water, bentonite formation may depend upon the presence of a significant amount of magnesium oxide (MgO) in the volcanic ash, since where magnesia is lacking, it does not alter to smectite. The alteration takes place concurrently or soon after accumulation of the volcanic ash rather than later or as part of the weathering process.

Smectite formation is actually the process of devitrification of the natural glass of the ash and the crystallization of the smectite. The ash will usually consist of an excess of silica and alkalis. The bentonites that swell the most are those which carry a sodium cation (Na^+) as the primary exchangeable cation.

Evidence suggests that at relative humidities below 30%, a calcium montmorillonite will form a skeletal double layer of water, rather than a single layer at a thickness of about $4.4\text{\AA}$. At relative humidities between 30% and 80%, two full layers develop with layer thickness increasing to $5.9\text{\AA}$. Sodium montmorillonite, dried at room temperature tends to develop a single water layer between the silicate layers with a spacing of about $12.5\text{\AA}$, while calcium montmorillonite under the same conditions develop two with a spacing of about $14.5\text{-}15.5\text{\AA}$. Sodium montmorillonite will absorb a far greater volume of water however, at high humidities and in the presence of a large quantity of water than calcium bentonite.⁸⁶

⁸⁶ For further discussion of clays, see Dorothy Carroll, *Clay Minerals: A Guide to Their X-Ray Identification* (Colorado: The Geological Society of America, Inc., 1970); Ralph E. Grim, *Clay Mineralogy* (New York: McGraw-Hill Book Company, 1968); C.S. Ross and E. V. Shannon, "Minerals of Bentonite and Related Clays and Their Physical Properties" *J. Am. Ceram. Soc.*, 9: 77-96 (1926); and Bruce Velde, "Composition and Mineralogy of Clay Minerals" *Origin and Mineralogy of Clays* (Germany: Springer-Verlag Berlin Heidelberg, 1995).

The chemical composition and physical properties of expansive clays, especially their hygrophilic character, must be considered in all aspects of study and treatment, including the development of a sample prototype and selection of treatment methods and materials.

2.4 Production of Samples

Approximately fifty samples of multi-layered mural paintings provided the means for testing various aspects of treatment as well as combinations of treatment. Of these nine samples were reserved for final tests.

The plaster composition was the same for all the sample groups. Each two layer sequence consisted of a ground layer composed of 50% lime, 40% bentonite, and 10% sieved sand; and a finish layer composed of 50% lime, 47% bentonite, and 3% sand mixed with enough water to create a material of medium thick, or yogurt-like consistency (approximately 1ml/g).

The first group of samples were unpainted and composed of multiple ground/finish plaster sequences brush applied to 12-by-12-inch concrete blocks and 6-by-6-inch gypsum wallboard panels.⁸⁷ These samples allowed the researcher to observe the response of the plasters to solvents, resins, and adhesives and their methods of application.

The second group of samples was composed of painted multiple ground/finish plaster sequences brush applied to 6-by-6-inch and 12-by-12-inch gypsum wallboard

panels. This group of samples was used to test treatments and materials. Evaluation was based on standardized tests and visual assessment of the effects of treatment on the optical properties of the painted plasters. These additional samples provided an opportunity to evaluate aspects of treatment prior to testing on the final group of facsimiles.

The third group of nine samples labeled A-J was reserved for the final testing program. Several combinations of methods and materials including preconsolidation, consolidation, and detachment, were tested on this group of samples. Each sample consisted of seven ground/finish plaster sequences brush-applied to 12-by-12-inch terra cotta panels. To ensure uniformity, a sufficient amount of plaster was always mixed to cover all the samples using the same batch.⁸⁸

The first six sequences were made from plaster using calcium bentonite. In order to represent the occurrence of increased deterioration and interlayer delamination at the surface observed in *in situ* plasters, the seventh and final sequence was made from the more expansive sodium bentonite clay.⁸⁹

⁸⁷ Plasters executed on concrete block exhibited the most severe conditions of powdering paint and interlayer detachment and were quite useful in the study of surface consolidants and preconsolidants.

⁸⁸ All the samples however, did not react similarly. Two to three samples out of ten inconsistently exhibited cracking in several of the campaigns. Discrepancies may have occurred due to inconsistent misting technique. Perhaps insufficient mixing of the plaster led to an uneven distribution of its components. The swelling, shrinking, and subsequent deformation of the plasters that occurred each time they were misted caused a loss of adhesion between layers and, at times, between the plaster and the substrate. Voids were detected below the plaster surface by tapping it lightly. The resulting plaster surface was friable and powdery to the touch.

⁸⁹ In preliminary laboratory testing, re-wetting of the ground plaster made from sodium bentonite resulted in significant weakening of its bond to the substrate. The newly applied finish layer cracked extensively, drawing with it, the ground plaster from the surface of the substrate.

Prior to application, the substrates were saturated with several spray applications of water to prevent them from absorbing moisture away from the plasters. In order to minimize the extensive cracking associated with rapid drying, samples were covered with sealed frames after each layer was applied. Covers were left in place for one day, but lifted periodically to allow for the samples to be misted with water. After 24 hours, the covers were removed. Samples were misted continuously throughout the second day and were then permitted to dry for an additional three days. After each layer was dry, it had to be re-saturated before the next layer could be applied. Murals were applied to each dry finish layer. Paintings required approximately two days to dry before additional layers of plaster could be applied.

Wall paintings

Mural facsimiles were copied from some of the Çatalhöyük paintings. On both preliminary test and prototype samples, motifs from the original murals were painted on the finish layer of each ground/finish sequence. Since a painting medium has not been identified, a paint type was selected with similar appearance to the original (matte, thin), compatible physical and chemical properties to the substrate, water solubility, and nominal alteration to the substrate.⁹⁰

⁹⁰ Watercolor was chosen as the paint most like that found at Çatalhöyük. Cotman watercolors, ivory black, made from gum arabic, dextrin, and nearly pure amorphous carbon, indian red, made from gum arabic, dextrin, and natural iron oxide; and yellow ochre, made from gum arabic, dextrin, and synthetic iron oxide, were used. Watercolor paints consist mainly of transparent pigments ground to an extremely fine texture added to an aqueous solution of gum arabic binder, which does not undergo any chemical change when it dries or dissolves. This type of paint dries by the evaporation of the solvent and involves no chemical reaction which would alter its nature. It may re-solubilize by the addition of more water to the dry material. Variations in the properties of hardening or solubility require that the binding material and the pigment must

The researcher attempted to create the most fragile sample type possible without inducing deterioration through accelerated aging.⁹¹ This was accomplished by applying a weaker pictorial layer lacking a strong organic binder on a plaster substrate made of expansive clay. It created a fragile system, similar to that found on site.⁹²

Division of final test samples

The group of samples reserved for final testing was divided into three parts. Six of the samples were set aside to be tested using the most successful treatments identified during preliminary testing. One sample was kept as a control. The last two samples were consolidated with ethyl silicates prior to detachment in order to represent research conducted on the consolidation of earthen plasters and mudbrick.

be combined in proportions appropriate to each specific color. The gum binder is thin, so watercolors tend to merely stain the substrate rather than form tangible distinct films. For further discussion see, Reed Kay, *The Painter's Guide to Studio Methods and Materials*, (New Jersey: Prentice-Hall, Inc., 1983) 128-131.

⁹¹ Accelerated aging was not carried out due to time constraints.

⁹² Loss of the painted surface occurred due to the saturation of the plaster required before application of each new layer.

Acid-Soluble Content: Results			
Sample	Mass ₁ (grams)	Mass ₂ (grams)	Percent Carbonates
Wall plaster 1 (Sample A)	25.16	11.80	53.10%
Wall plaster 2 (Sample C)	24.93	9.97	60.05%
Relief plaster 1 (Sample B)	3.69	1.77	52.03%
Relief plaster 2	33.32	16.00	51.98%
Mud brick (Sample D)	21.57	18.54	14.05%

Fig. 19. Acid-soluble content of wall and relief pasters. Note high carbonate content. From Kopelson, Evan. "Analysis and Consolidation of Architectural Plasters from Çatalhöyük, Turkey." Master's thesis, University of Pennsylvania, 1996.

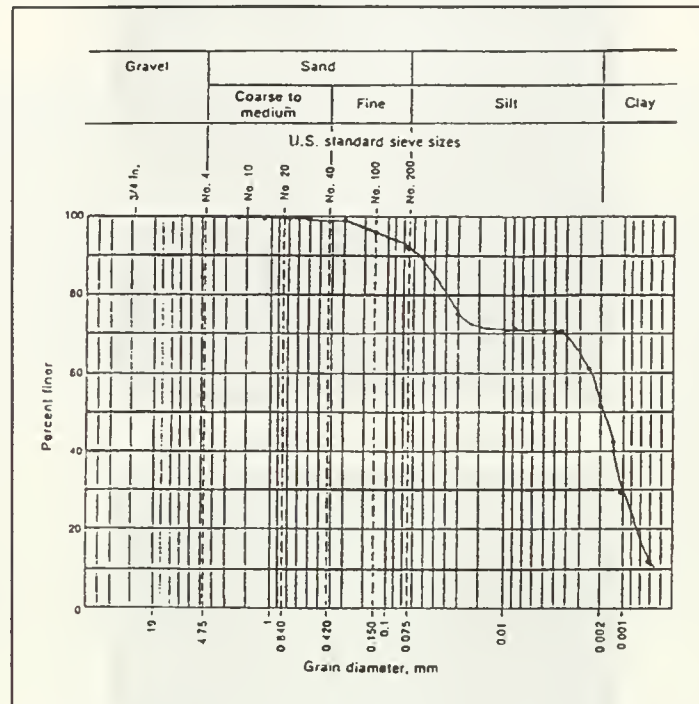


Fig. 20. Particle size distribution of wall plaster primarily composed of silts and clays with very few sand-sized particles. From Kopelson, Evan, "Analysis and Consolidation of Architectural Plasters from Çatalhöyük, Turkey," (master's thesis, University of Pennsylvania, 1996).

Particle Size Distribution: Dry Sieving Results				
Wall Plaster			Relief Plaster	
Initial Mass:	101.37 grams		Initial Mass:	102.49 grams
Mass retained (g)	Percent passing	Sieve diameter (mm)	Mass retained (g)	Percent passing
0.14	99.86 %	2 . 3 6	0	100 %
0.13	99.73	1 . 1 8	0.05	99.95
0.32	99.41	0 . 6 0 0	0.10	99.85
0.83	98.59	0 . 3 0 0	0.80	99.07
2.28	96.34	0 . 1 5 0	3.52	95.64
4.35	92.05	0 . 0 7 5	4.71	91.04
2.10	—	p a n	0.54	—

Fig. 21. Results of dry sieving. From Kopelson, Evan, "Analysis and Consolidation of Architectural Plasters from Çatalhöyük, Turkey," (master's thesis, University of Pennsylvania, 1996).



Fig. 22. Mural painting replica Finish layer 1



Fig. 23. Mural painting replica: Finish Layer 2



Fig. 24. Mural painting replica: Finish layer 3



Fig. 25. Mural painting replica: Finish layer 4



Fig. 26. Mural painting replica: Finish layer 5



Fig. 27: Mural painting replica: Finish layer 6

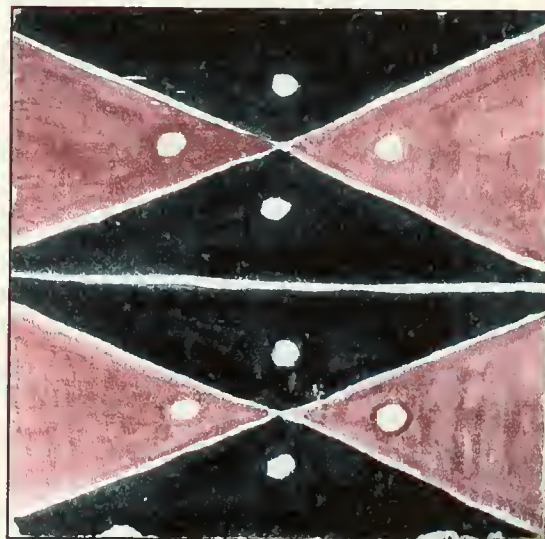


Fig. 28. Mural painting replica: Finish layer 7

Chapter 3: Testing Program

This phase of research aimed to inform the on-site treatment of the murals at Çatalhöyük. Two phases of intervention were determined to be essential and became the focus of research. The first, preliminary methods for stabilization, aimed to treat surfaces in need of immediate stabilization and to prepare them for removal. The second type of intervention focused on the development of methods for detaching the mural paintings. Methods and materials were tested on simulated samples under laboratory controls.

Summary:

This chapter describes the laboratory research developed to inquire into effective wall painting detachment methods for Çatalhöyük. In six parts, it handles the development and execution of treatment systems and methods for their evaluation. It begins with Section 3.1, a description of the condition of the painted plasters on site and requirements for their treatment. Section 3.2, “Preliminary Testing A” describes the testing program in which individual materials were considered to treat several distinct conditions before detachment. Section 3.3, “Evaluation of Preliminary Testing A” describes the methods by which these individual phases of treatment were assessed. Because a combination of treatments is often required to combat the numerous problems encountered by painted earthen plasters following excavation, Section 3.4, “Preliminary Testing B,” describes the program designed to address the compatibility of the successful treatments indicated in Sections 3.2 and 3.3. Section 3.5 describes the final testing program, which focused on the most successful treatments identified during preliminary

testing. Section 3.6 offers an evaluation of the results of the final testing program.

Supporting data and conclusions are located in Chapter 4.

3.1 Introduction

The condition of wall plasters and murals at Çatalhöyük varies depending on location within the site and degree of exposure. Many paintings protected by overlying plaster layers or infill remain in good condition. Field and laboratory examination of exposed paintings however, revealed problems common to archaeological wall paintings, such as degradation caused by changes in atmospheric pressure or relative humidity following excavation. The crystallization of salts due to water infiltration, macro-biological growth, erosion of the plaster surface, decomposition of the paint layer, cracking of the paint and plaster layers, interlayer detachment, delamination from the wall support, and surface accretions are problems often identified at archaeological sites.⁹³

The plasters and mural paintings at Çatalhöyük show a loss of cohesive strength within discreet layers and a loss of adhesive strength between individual layers. Most of

⁹³ For further information see, O.P. Agrawal and Kamal K. Jain, "Problems of Conservation of the Wall Paintings in India" *International Symposium on the Conservation and Restoration of Cultural Property* (Tokyo: Tokyo National Research Institute of Cultural Properties, 1984) 31-39; Wesley Bliss, "Preservation of the Kuaua Mural Paintings" *American Antiquity*, No. 3, 1948, p. 218-223; H. Hodges, *Neolithic wall paintings: problems of conservation* (IIC United Kingdom Group, 1964); Sergio Arturo Montero, "The Conservation of Archaeological Painting" *In Situ Archaeological Conservation, Proceedings of Meetings: April 6-13, 1986*. Ed. Henry W. M. Hodges (Mexico: Instituto Nacional de Antropología e Historia and California: The J. Paul Getty Trust, 1987) 98-105; Watson Smith, "Kiva Mural Decorations at Awatovi and Kawaika-a. Papers of the Peabody Museum of American Archaeology and Ethnology" Vol. 37 (Massachusetts: Peabody Museum, 1952) 34-35; Constance Silver, "Architectural Finishes of the Prehistoric Southwest: A Study of the Cultural Resource and Prospects for its Conservation" (masters thesis: Columbia University,) 115-118; and Qi Yingtao, "Studies on Conservation of the Grotto Temples and Mural Paintings of Ancient Graves in China" *International Symposium on the Conservation and Restoration of Cultural Property* (Tokyo: Tokyo National Research Institute of Cultural Properties, 1984) 19-29.

the delamination occurs in the outermost plaster layers. As excavation continues, and the requirement for surface stabilization increases, it will be necessary to implement effective treatments. One of the first aspects of such treatment is application of the appropriate preconsolidant and/or consolidant.

Function of Preconsolidant:

Since consolidation of the plaster may not immediately effect the paint layer, and since consolidation of the plaster may not always be feasible, it is necessary to develop methods for treating surfaces separately. The function of a preconsolidant is to impart strength to the surface and to enable additional treatment.

Function of Consolidant:

Application of a consolidant is necessary when the primary or secondary bonds holding a material together have been broken. Dissolution in a solvent carrier allows the consolidant to penetrate deeply into a material, in this case earthen plaster, and strengthen it by binding loose particles together. Its main function is to increase intergranular cohesion.

Function of an Adhesive:

Adhesives may be made of natural or synthetic materials. They are used to treat cleavage, flaking paint and plaster by filling gaps between pieces, adhering to both surfaces and providing an adequately strong and rigid interface between pieces.⁹⁴

Wall paintings located in rooms that had been burned at the time of occupation exhibit more complicated problems. Burned paint cracked and fell off the walls. The paint layers themselves were very thin and prone to disintegration. The resulting heat sometimes fused the paintings to underlying layers or to the mudbrick wall supports. In addition to natural deterioration mechanisms, continued excavation of the site places the remaining paintings at risk of destruction.

3.1.1 Detachment Techniques

Various methods for removing murals have been developed over the past 100-150 years. These primarily European methods, have usually responded to murals executed on lime renders as opposed to clay-based renders. Three primary detachment techniques differ by their level of removal. They are *stacco a massello*, the removal of a painting with all or part of its supporting wall; *stacco*, the removal of a painting with its rendering; and *strappo*, the removal of the paint layer alone.⁹⁵ They provide the reference for developing removal and reattachment methods for murals on clay supports, such as those at Çatalhöyük.

⁹⁴ Andrew Wheatcroft, ed., *Science for Conservators Volume 3: Adhesives and Coatings* (London: The Conservation Unit of the Museums and Galleries Commission, 1987) 14.

⁹⁵ A brief history, detailed review of detachment techniques, and related case studies may be found in Appendix B.

Two types of detachment techniques were used previously at Çatalhöyük. The “block method,” in which portions of the mudbrick wall were removed with the painted plaster; and the “peeling method,” in which consolidated paintings faced with Japanese tissue, fine linen, and size, are peeled from the support with a portion of mud plaster still adhering, were used with varying degrees of success.⁹⁶ Conservation reports describing these methods combined with a literature review of related case studies provided the foundation for a research design.

3.1.2 Requirements of Research

Based on conditions at the site, several specific problems were identified as requiring immediate treatment before removal. Treatments for these conditions were tested in the laboratory.

Conditions:

- Loss of cohesion in paint (powdering paint)
- Loss of cohesion in surface lime-based renders (powdering plaster)
- Loss of adhesion between plaster layers (interlayer detachment)
- Surface cleaving and cracking
- Loss of cohesion in earthen plasters (disaggregation)

⁹⁶ Previous treatments, as described in reports written by Pamela French, dating from 1968-1974 have been summarized in Appendix A. Pamela French, “Report on work carried out on the murals from Çatal Hüyük in the Archaeological Museum, Ankara in September 1968;” “Report to the British Academy on the work done on the Çatal Hüyük Paintings;” “The Çatal Hüyük Wall Paintings;” “The Continuation of the Conservation of the Çatal Hüyük Wall Paintings undertaken in the Museum of Anatolian Cultures, Ankara, Summer, 1973;” and, “Report to the British Academy on the Conservation of the Çatal Hüyük Wall Paintings, Summer 1973, Spring 1974.” unpublished reports.

In order to address these conditions, certain preliminary stabilization treatments had to be tested in addition to various types of wall painting detachment. Specific tests included:

Treatments:

- Consolidation of the painted layer
- Consolidation of lime plaster
- Reattachment between plaster layers
- Flattening of cleavage
- Selection/application of facing adhesives for mural detachment
- Selection/application of detachment methods
- Compatibility of treatments.

Treatments were tested on laboratory facsimiles. Tests were selected according to the treatment objective, the types of material to be treated, and the nature of deterioration. Past research focusing on detachment methods was considered.

A selection of materials representing traditional and current practice on similar materials and conditions in the field of conservation were chosen for preliminary study. This study aimed to determine which, if any, traditional and/or non-traditional materials would consolidate the plaster and friable paint without altering their optical properties, permit the detachment of the plaster or paint layer from the substrate; and be retrievable.

The effects of adhesives, fixatives, preconsolidants and consolidants, alone and in combination, were observed on facsimile samples made of three to six layers of painted plaster on gypsum board substrates.

3.1.3 Materials: Adhesives and Consolidants

A selection of materials representing a range of adhesives and consolidants was considered for testing. They included natural and synthetic materials chosen from seven groups of adhesives and consolidants: collagen-based adhesives; acrylic resins; acrylic emulsions; gums; polyvinyl acetate emulsions; polyvinyl alcohol; and waxes. It was important that the materials selected were affordable, exhibited low toxicity, and did not present a fire hazard. The performance of each was observed at various concentrations according to its function.⁹⁷ Adhesive mixtures were also studied. The following is a brief description of each.

- Thermoplastic acrylic resins: Acryloid B-67

Acryloid B-67 is an isobutyl methacrylate polymer commonly used in the conservation of paintings and objects. It is durable, flexible, resistant to discoloration, and to water, alcohols, alkalis and acids. It does not become insoluble or degrade significantly under normal conditions of exposure.⁹⁸ B-67 may be obtained commercially as solids or in a 45% solution in mineral spirits. For this research, it was tested as both a preconsolidant and a facing adhesive.

⁹⁷ The functions of surface consolidation, readhesion, and facing adhesion require materials with different concentrations. For example, since it is not desirable for a facing adhesive to penetrate the surface of a painting, a higher concentration would be required than if the same material were used to consolidate a painted surface. See specific tests for most successful applications.

- Thermoplastic acrylic resins: Acryloid B-72

Acryloid B-72 is an ethyl methacrylate copolymer used for the consolidation of paintings and objects. In addition to the properties listed above (see Acryloid B-67), its low reactivity with sensitive pigments made it especially desirable for this project. Its use in the field of art conservation is well established and documented.⁹⁹ Acryloid B-72 may be obtained commercially in solids and as a 50% solution in toluene. It was tested as a surface consolidant and as a facing adhesive.

- Acrylic emulsion: Rhoplex AC-33

During the first phases of testing, Rhoplex AC-33, a low viscosity acrylic resin emulsion was studied. Under optimum conditions, it is known to dry to a clear firm film that does not degrade under normal conditions of exposure. For this research, it was tested as a preconsolidant.

- Acrylic emulsion: Plextol B500

Plextol B500 is an aqueous emulsion of a thermoplastic acrylic polymer of ethyl acrylate and methyl methacrylate. It forms a clear colorless film that remains elastic at room temperature and is soluble in most organic solvents. It has been used as a binder for

⁹⁸ C.V. Horie, *Materials for Conservation* (London: Butterworth & Co., Ltd., 1987), 106-109.

⁹⁹ A testing program developed to evaluate the performance of seven different surface consolidants on the basis of specific ideal properties was carried out at the Instituto Centrale del Restauro. Tests were designed to measure the adhesive and cohesive strength of the treated surface, resistance to abrasion, solubility, alterations in optical properties, resistance to biodeterioration, and reaction to the effects of accelerated aging. The materials studied were Calaton CA, Primal AC33 (also known as Rhoplex AC33), Primal AC55, Acryloid B-72, Lucite 45, commercial white shellac, and Gelvatol 40-20. Acryloid B-72 in a 5% solution in toluene demonstrated the best overall performance for the criteria. Cited in Constance Silver, "Architectural Finishes of the Prehistoric Southwest: A Study of the Cultural Resource and Prospects for its Conservation" (master's thesis, Columbia University, 1987), 145-146.

pigmented coating and exhibits the desirable properties of resistance to weathering and aging. It was selected for testing as a facing adhesive.

- Collagen-based adhesive: rabbit skin glue

Rabbit skin glue is a natural high polymer organic colloid made from mammalian collagen, the primary protein of skin, bone, and sinew. These collagen molecules are connected by a few covalent and many hydrogen bonds. Rabbit skin glue is sold in granule form and reactivated by soaking in water and heating until dissolution. Due to its molecular configuration, it has the ability to shift easily and repeatedly between viscous and firm states by simple heating and cooling. These molecules are long and flexible and take a helicoidal form in solution. The gelatin swells when set in cold water for at least three hours. It must be heated prior to use to a temperature not exceeding 60°C. As it cools, the glue passes through a tacky phase before returning to a gel state. It hardens quickly into a dried film as water diffuses into the substrate and the gel begins to form. The gelatin eventually returns to its original dry state, its contraction rate relating directly to the amount of water used to make the solution.¹⁰⁰ Rabbit skin glue was initially considered as an adhesive.

¹⁰⁰ For further information, see: John R. Hubbard, "Animal Glues," in *Handbook of Adhesives* (New York, New York: Van Nostrand Reinhold Company Inc., 1977); C.V. Horie, *Materials for Conservation* (London, England: Butterworth & Co. Ltd., 1987) 142-143; Arthur H. Landrock, *Adhesives Technology Handbook* (Park Ridge, New Jersey: Noyes Publications, 1985), 160; and Liliane Masschelein-Kleiner, *Ancient Binding Media, Varnishes and Adhesives* (Rome, Italy: ICCROM, 1985), 66-68.

- Collagen-based adhesive: gelatin

Gelatin is a proteinaceous organic compound made up of large molecules of high molecular weight. Like rabbit skin glue, it is an animal product derived from collagen which appears slightly yellow in its natural dried form and remains flexible due to its water content. Dried gelatin will swell to many times its normal volume when immersed in water, dilute acids or alkalis. This colloid which produces highly viscous solutions, is widely used as a light adhesive for conditions such as flaking paint.¹⁰¹ Gelatin was initially considered as an adhesive.

- Gums: gum arabic

Gum arabic is derived from the Acacia tree found in Africa, India and Australia. It is a non-crystalline amorphous substance composed predominantly of carbon, hydrogen and oxygen. Plant gums in general are “salts of complex organic acids, usually with calcium, magnesium, and potassium.” Sugar units combine with the acidic part of the molecule to form complex acids. They are crushed or ground to a powdered form and mixed with boiling water before use as a strong adhesive or binder.¹⁰² Gum arabic was initially selected for use as an adhesive.

- Polyvinyl alcohol

Polyvinyl alcohol is produced by the hydrolysis of polyvinyl acetate. It is soluble in water, resistant to light, and uncomplicated to use. Films derived from this resin

¹⁰¹ For further information, see Rutherford J. Gettens and George L. Stout, *Painting Materials: A Short Encyclopedia* (New York: Dover Publications, Inc., 1966), 25; H.J. Plenderleith and A.E. Werner, *The Conservation of Antiquities and Works of Art* (London: Oxford University Press, 1971), 169-170.

demonstrate strength, flexibility, and resistance to petroleum solvents, oils, and fats.

Various concentrations of polyvinyl alcohol in water were tested to find the most appropriate for use as a facing adhesive. A 20% solution proved to be the least concentrated mixture that could be used without penetration of the plaster surface.

Polyvinyl alcohol was tested as a facing adhesive for mural detachment.

Data from initial testing was utilized and expanded upon in section 3.2.5, *Readhesion/Facing Adhesives*. Successful treatments from previous tests were combined to evaluate their compatibility.

- Waxes: Microcrystalline wax

Microcrystalline waxes are made up of very thin crystals dispersed in an amorphous, viscous material. The wax is normally prepared by melting in a double boiler and mixing it with polyterpene resin. It is known for its properties of adhesion and flexibility. It has been used successfully in conjunction with the application of gentle pressure and heat to reattach flaking paint and relax cleavage.¹⁰³ The proportion of microcrystalline wax to polyterpene resin used in this program for the purposes of reattaching flaking plaster and paint was 3:1.¹⁰⁴ Microcrystalline waxes were tested for treatment of surface cleavage and flaking.

¹⁰² For further information, see Rutherford J. Gettens and George L. Stout, *Painting Materials, A Short Encyclopedia* (New York: Dover Publications, Inc., 1966), 28-29.

¹⁰³ For further information, see H.J. Plenderleith and A.E. Werner, *The Conservation of Antiquities and Works of Art* (London: Oxford University Press, 1971), 169-170.

¹⁰⁴ Conservation Materials Ltd. "The Keck Formula" in *Conservation Materials Ltd. Catalog* (Nevada: Conservation Materials Ltd. nd.), 35.

- Polyvinyl acetate emulsion: Vinamul 6825

Vinamul 6825 is a polyvinyl acetate emulsion miscible in water. It is recommended as a consolidant for non-metallic objects except when penetration is required. It has been used as a facing material for wall paintings in climates unsuitable for glue.¹⁰⁵ Product literature recommends a concentration of one part emulsion to three parts water. Vinamul 6825 was tested for use as a facing adhesive.

- Traditional adhesive: “*colletta*”

Colletta is a collagen-based adhesive developed for the detachment of wall paintings by the methods of *stacco* or *strappo* at the Istituto per il Restauro in Rome.¹⁰⁶ A variety of concentrations of both the *strappo* and *stacco* formulas were tested to identify the least concentrated solution capable of effectively detaching the painting. Preliminary *stacco* and *strappo* tests utilized the *colletta* glue at full strength. Lower concentrations were evaluated in subsequent tests to minimize the strength of the facing adhesive during removal. *Colletta* was tested as a facing adhesive for mural detachment.

3.2 Preliminary Testing A: Individual tests

Preliminary research program “A” is outlined in the following pages. Data and conclusions are located in Chapter 4.

¹⁰⁵ Conservation Resources (U.K.) Ltd. *Chemical Data Sheet: Vinamul 6825 (6815)*(England: Conservation Resources (U.K.) Ltd., 1992).

¹⁰⁶ The recipe used for the *stacco* method is a mixture of bone glue soaked in water for twelve hours until swelled, then heated until fluid, then mixed with molasses which is used as a plasticizer; vinegar, used as a fluidizer; oxgall, used as a surface active agent; and a small amount of fungicide. Because the *strappo*

3.2.1 Test for Visible Alteration of the Plaster Surface

Summary:

Prior to testing a combination of materials, the components of each material were individually evaluated based on visual assessment.

Objective:

The aim of this test was to observe possible alteration to plasters caused by solvents, adhesives, and consolidants.

Methodology:

A simple testing program was devised to observe the visual effects of adhesives, solvents, and consolidants on the surface of the facsimile plasters. This test was conducted on one 6- by-6- inch unpainted multi-layer sample on gypsum board. Twine and tacks created a sixteen square grid. Several drops of the following materials were applied to separate cells within the grid: water, ethanol, isopropanol, acetone, rabbit skin glue (5% in water), Acryloid B-72 (7% and 10% in xylene), and Aquazol50® (5% and 10% in water, ethanol, and isopropanol), a 50/50 preconsolidant mixture of Aquazol50® (5% in ethanol)/T-1919®, and pure T-1919. Results, such as darkening, cracking, and gloss were observed and recorded in Table 6.

method depends upon contraction of the glue to detach the painting, the plasticizer is omitted from the mix..

Observations:

Undesirable results such as the formation of a glossy film, discoloration of the surface, and cracking, indicated that rabbit skin glue, Acryloid B-72®, and Aquazol 50® required further observation before they could be considered for the final testing program.¹⁰⁷

¹⁰⁷ One of the biggest challenges in the consolidation of matte paint is the preservation of the optical properties of the painted surface. Darkening of the surface due to the formation of a glossy film is a common problem. One solution is to treat the sample using multiple applications of dilute solutions of the consolidating agent. For further information, see Eric F. Hansen, Rosa Lowinger, and Eileen Sadoff, "Consolidation of Porous Paint in a Vapor-Saturated Atmosphere. A Technique for Minimizing Changes in the Appearance of Powdering, Matte Paint," in *Journal of the American Institute for Conservation*, Volume 32, No.1 (Spring 1993): 1-14.

3.2.2 Test for Surface consolidation

Summary:

The plasters and paint layers at Çatalhöyük are detached and there is loss of adhesion between paint and plaster layers. The paints have also lost cohesive strength. These conditions may require preliminary treatment aimed at readhering separated layers, reattaching paint and flaking plasters, relaxing cleavage, and reestablishing cohesion within the paint layers.

Objective:

The aim of surface consolidation testing was to identify a material that will strengthen the surface of the plaster while preserving its original appearance.

Methodology:

Adhesives were brushed onto the surface of a preliminary test sample (an unpainted multi-layer plaster sample on concrete block) through Japanese tissue. The condition of the plaster was comparatively stable prior to testing. Changes in surface appearance are noted in the table below. Results were qualitatively assessed.

Observations:

All of the adhesives, except gelatin in a 5% solution in water were successful at decreasing the friability of the plaster surface. Undesirable effects however, such as discoloration and residue sometimes accompanied the strengthening. Aquazol 50® in 5% solutions in ethanol and water, and Acryloid B-72 in a 5-15% solution in toluene attained the most favorable results. Data is located in Table 7.



Fig. 29. Results of test aimed to strengthen the surface of the plaster while preserving its original appearance

3.2.3 Test for Surface Consolidation and Preconsolidation with Readhesion, Part I

Summary:

Detachment of the plaster layers at Çatalhöyük occurs most often in outermost layers, farthest from the mudbrick substrate. This condition appears to result from salt crystallization, macro-biological growth, and/or changes in the ambient atmosphere during excavation. Treatments were needed to preconsolidate the plaster surface and to readhere delaminating layers.

Objective:

The aim of this test was to identify materials capable of increasing the cohesive and adhesive strength of the plaster surface without alteration of its optical properties and to improve interlayer attachment between plaster layers exhibiting cleavage and separation.¹⁰⁸

Methodology:

Adhesives were brushed through Japanese tissue onto an unpainted 6" gypsum board panel coated only with a layer of sodium bentonite mixed with water. Prior to treatment, the clay plaster exhibited severe shrinkage cracking with extensive cleavage and cupping. Areas that swelled during treatment were covered by silicone release mylar and manipulated by lightly rolling over the surface with a glass stirring rod. Pressure was then applied by weighting them with 2-inch marble cubes. Reaction to treatment and changes in surface appearance and condition are noted in the following table. Weighted

¹⁰⁸ These tests were conducted in conjunction with one another.

samples have been identified as such. Results were qualitatively assessed and are listed in Table 8.

Observations:

Three of the nine treatments produced acceptable results. Aquazol 50® in a 5% solution in water strengthened weak friable surfaces. Gelatin in a 5% solution in water partially relaxed cleavage and promoted readhesion with only a slight darkening of the surface. Water was applied to two different test cells. In the first case, it demonstrated the best performance by relaxing cleavage, promoting readhesion and decreasing friability without visual alteration of the surface. The second application however, began to dissolve the clay film. Cleavage was partially relaxed but began to cup again while drying. Test results indicated that further study was required.

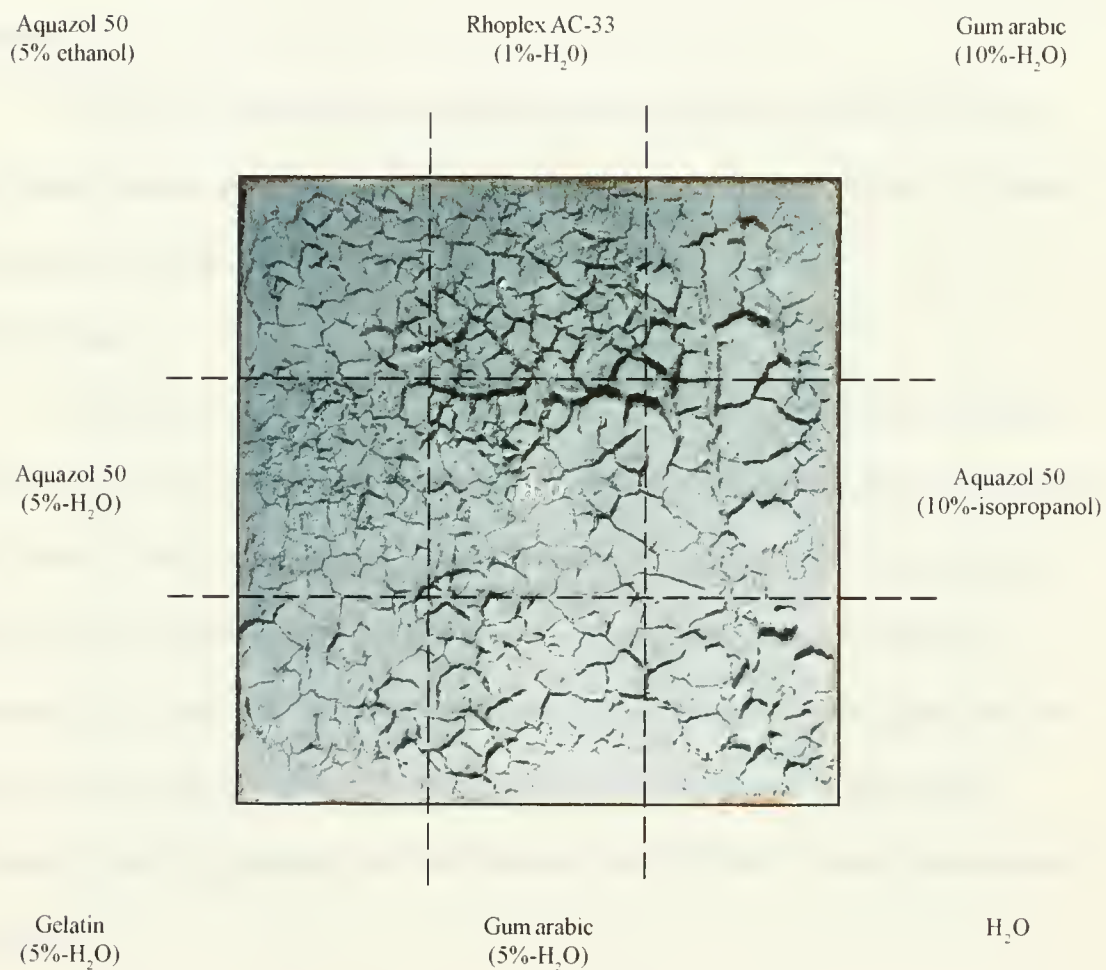


Fig. 30. Results of test for surface consolidation and preconsolidation with readhesion. (Part I)

3.2.4 Test for Surface Consolidation and Preconsolidation with Readhesion, Part II

Summary:

This test continued the aims of Preconsolidation and Surface Consolidation with Readhesion, Part I.

Objective:

The aims of this test were to strengthen the plaster surface while preserving the original appearance and to improve interlayer attachment between plaster layers exhibiting cleavage and separation.

Methodology:

Treatments were applied to a 12-by-12-inch multi-layer painted concrete block. The condition of the plaster prior to testing was quite poor, exhibiting delamination from the substrate, interlayer separation and a very friable surface. Adhesives were brushed onto the surface of the sample through Japanese tissue. Samples that swelled were covered with silicone release Mylar and manipulated slightly by rolling lightly over the surface with a glass stirring rod. They were then weighted with 2" marble cubes. Changes in surface appearance and condition are noted in Table . Results were assessed in Table 9.

Observations:

Aquazol 50® in 5% solutions in water and ethanol and gelatin in a 5% solution in water decreased friability and promoted adhesion but caused a slight darkening of the plasters. The use of water again produced positive results by increasing readhesion to the substrate.

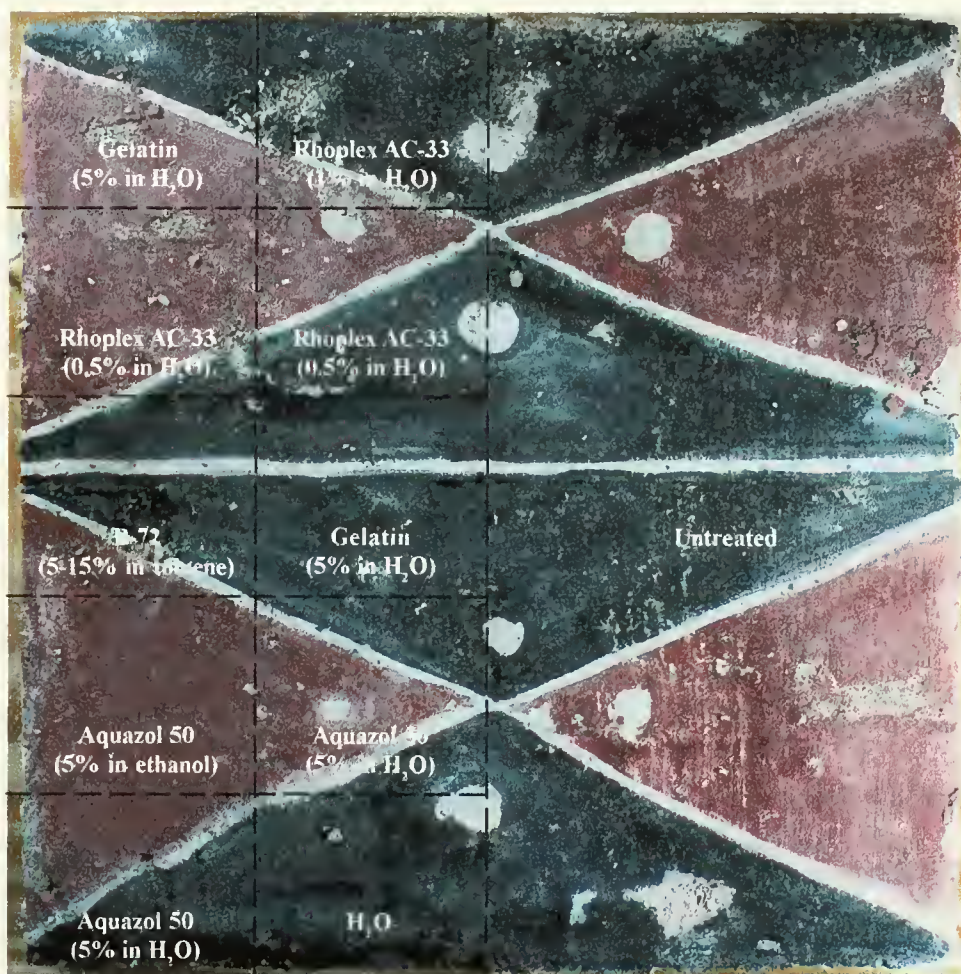


Fig. 31. Result of test designed to assess surface consolidation, preconsolidation, and readhesion treatments (Part II)

3.2.5 Test for Readhesion/Facing Adhesives

Objective:

This test considers the effects and relationship of two treatments. The first addresses adhesion between detached plaster layers and between the plaster and the substrate. The second treatment, which relies on the success of the first, concerns attaching a tissue facing to the surface without penetration of the adhesive into the plaster.

The selection of a facing adhesive depends upon several factors: resistance of the paint layer to water or to other solvents required for the detachment procedure, the degree of humidity of the environment in which the work is to take place, the method of detachment, the reversibility of the adhesive, and the state of preservation of the wall painting. Because the paint layer was weak and water-soluble, it was necessary to improve its resistance. Evaluation of facing adhesives was carried out to identify a reversible adhesive capable of adhering a tissue facing to the plaster surface without penetration.

Methodology:

The following tests were carried out in conjunction with one another on a 24-by-24-inch painted multi-layer gypsum board panel (D) divided into nine treatment sections. The condition of the plaster prior to treatment was extremely poor, exhibiting severe cracking, interlayer separation, and extensive delamination from the substrate. Two additional conservation materials were studied, microcrystalline wax, and Plextol B500. The first test area, D1, was treated with an application of Acryloid B-72 in xylene. After that, it was divided in half and treated as D1A and D1B, respectively. Section D2 was

treated with a spray application of water. Following that, it was divided into D2A and D2B. The remainder of the sample sections was treated as single units. Treatment details, assessed qualitatively, are described briefly in Tables D1 through D9.

Observations:

The use of Acryloid B-72 as a surface consolidant prevented losses in the paint layer previously caused by the application of water and other aqueous substances used for preconsolidation. Darkening of the plaster however, indicated the need to experiment with more dilute solutions. The combination of B-72 as a surface consolidant with water or Aquazol 50® in a 5% solution in water produced encouraging results. Readhesion was improved, cleavage was relaxed, and both treatments allowed for manipulation of the surface without damage to the plaster. Results of tests using microcrystalline wax and Plextol B500 were unsatisfactory. Incomplete penetration of the wax resulted in a darkened film left on the surface of the plaster. Plextol B500 was brushed through Japanese tissue. Attempts to remove this tissue caused full-scale detachment of the plaster, indicating that the adhesive, although inappropriate for use as a preconsolidant, might prove useful as a facing adhesive in later detachment tests. Results are located in Tables 10 and 11.

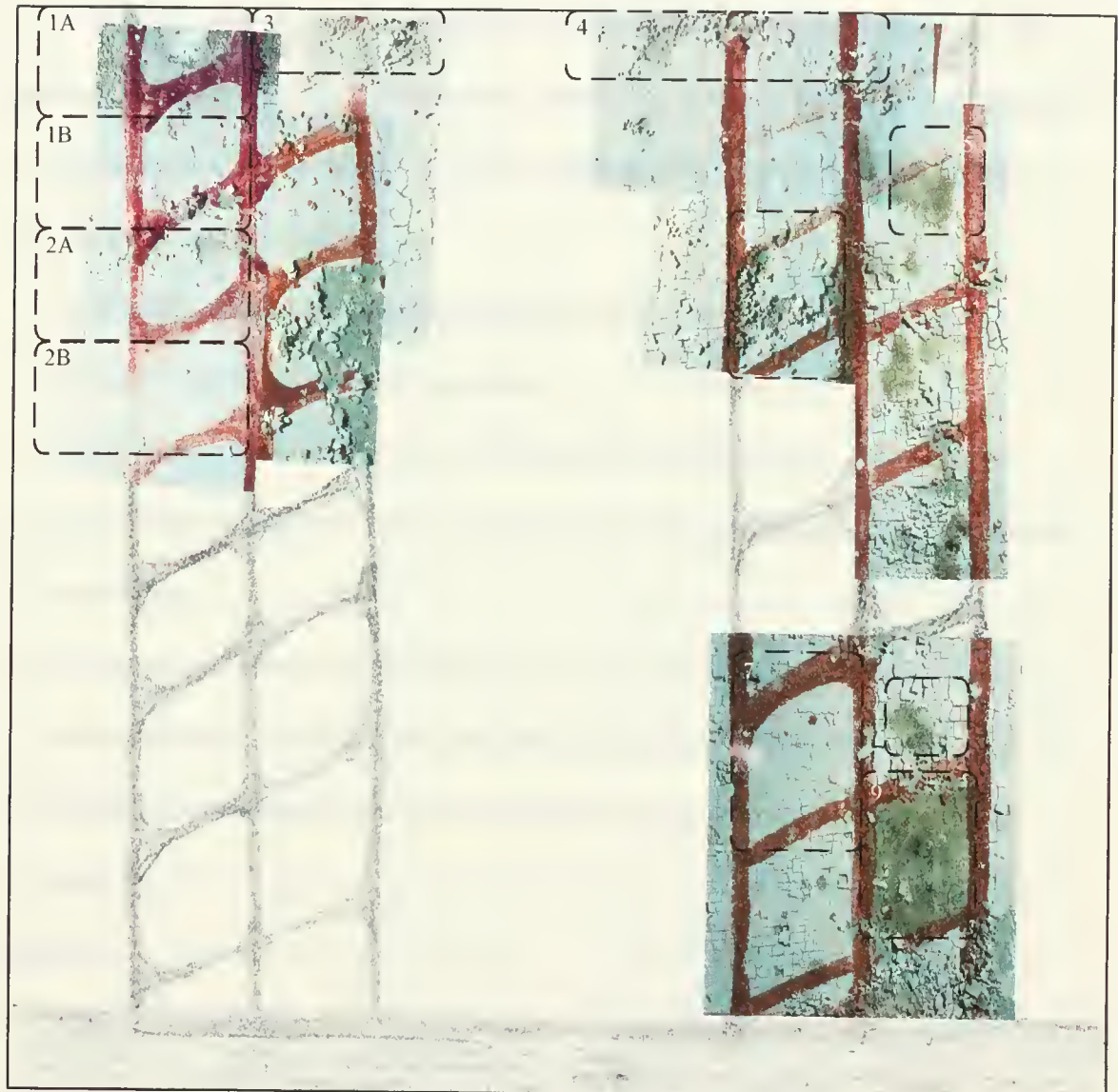


Fig. 32. Results of test considering the treatment of detached plaster layers and pieces in conjunction with the attachment of facing adhesives.

3.2.6 Test for Surface Consolidation of Powdering Paint with Consolidation and Readhesion

Summary:

Surface consolidation may be required to arrest cohesion loss, flaking, or other types of deterioration of a painted surface. Ideal properties of a surface consolidant are:

- The material must be capable of quickly bonding loose particles or flakes of paint or rendering to the support.
- Penetration must be sufficient to establish a bond to the underlying layers
- Residue must be soluble and removable
- Flexibility should be sufficient to withstand mechanical shock.
- The material should be clear and should not alter the optical properties of the plaster or painting.
- Any surface treatment should offer resistance to biological and atmospheric deterioration as well as to static electricity and the accumulation of dust.
- Ideally, the consolidant should remain soluble in case removal is required in the future.¹⁰⁹

Objective:

The purpose of the test was to treat the loss of adhesion and cohesion of the paint layers without altering the optical properties of the plaster or painting.

¹⁰⁹ Paolo and Laura Mora, Paul Philippot, *The Conservation of Wall Paintings* (London: Butterworth's, 1984), 217-222.

Methodology:

The following test was carried out on three 12-by-12-inch painted multi-layer gypsum board panels. The aim was to determine whether the plaster could be consolidated after the application of a surface consolidant. The materials were either brushed on or spray applied as noted in the following tables. After treatment, the surface was weighted. Results are described in Tables through .

Observations:

The application of Acryloid B-72 as a surface consolidant prevented losses in the paint layer without disturbing the effectiveness of the preconsolidant treatment. Applications of both water and Aquazol 50® (5% in water) facilitated flattening of cleavage and readhesion of small pieces of plaster to the substrate. In addition, water followed by the application of pressure appeared to improve compaction of the plasters by decreasing voids between separated layers. Aquazol 50® (5% in water) strengthened the bond between plaster pieces. The application of Aquazol 50® (5% in isopropanol) facilitated flattening of cleavage and strengthened the bond between plaster pieces, however, it caused a yellow discoloration of the surface. Results of the combination of Acryloid B-67 and Acryloid B-72 treatments were unacceptable because although the crumbly plaster layer appeared stronger, the surface was significantly darkened and delaminated pieces were not readhered to the substrate. Data is located in Tables 12, 13, and 14.



Fig. 33. Combination of treatments. Top row: Acryloid B-72 (8% in xylene) x 3, followed by water.
Bottom row: Acryloid B-72 (3% in xylene) x 2, followed by Aquazol50 (5% in water)



Fig. 34. Combination of treatments. Acryloid B-72 (3% in xylene) x 2, followed by water



Fig. 35. Combination of treatments. Acryloid B-67 caused discoloration of the lower left hand corner.

3.2.7 Facing Adhesives: Methods and Materials - Preparation for *Stacco* and

Strappo

Summary:

The selection of facing adhesives was based on the conditions previously outlined in “Readhesion/Facing Adhesives.” Requirements for removal include removal with minimal risk to the painted surface and easy dissolution. The following tests assess the ease of facing and residue removal of traditional and non-traditional adhesives.

Objective:

The aim of this study was to adhere a tissue facing to the surface of a multi-layer painted plaster sample, permit it to dry, and then remove it without causing damage or alteration of optical properties. These tests determined the reversibility and suitability of the following facing adhesives for *stacco* and *strappo*:

- *Colletta*: full strength
- Polyvinyl alcohol: 20% in water
- Acryloid B-72: 20% in xylene
- Acryloid B-67: 20% in mineral spirits
- Plextol B500: 50% solids
- Vinamul 6825: 50% solids

Methodology:

Six facing adhesives were applied to six 6 x 6 inch painted multi-layer panels. Two of the adhesives, *colletta* and polyvinyl alcohol, are water-soluble.¹¹⁰ Two thermoplastic acrylic resins, Acryloids B-67 and B-72, are soluble in hydrocarbons. A layer of adhesive was brushed onto the surface of the plaster. The tissue was applied directly to the glue-coated surface and another layer of adhesive was brushed on top of that. The adhesives were permitted to cure for approximately seventy-two hours. Then, a poultice was applied to soften the adhesives in preparation for their removal. Residue was removed using the appropriate solvent and cotton swabs or pads. Results are outlined in Tables 15 and 16.

Observations:***Colletta:***

Applied to the plaster at full strength, *colletta* formed a strong bond between the plaster and the tissue facing within minutes. Contraction of the glue caused partial delamination from the substrate. Poultice applications and blotting of the plaster surface with pads soaked in hot water to remove the residue of the adhesive caused severe swelling of the clay plasters. Mechanical removal of the residue was only partially successful. *Colletta* was embedded between the brushstrokes of the plaster. Complete reversibility through poultice application and mechanical removal was impossible. Both pigment and plaster losses were substantial. The surface was slightly discolored.

Acryloids B-67 and B-72:

20% solutions in mineral spirits and xylene were very viscous.¹¹¹ Results of the removal of the facings applied with thermoplastic acrylic resins were poor. The panel faced with Acryloid B-72 required the application of xylene poultices for six hours before the facings could be removed. The procedure caused minor swelling of the clays and some separation between those layers where deterioration already existed. Residue removal was unsuccessful and a great deal of effort produced little result. Some pigment loss occurred. A residual glossy film caused a darkening of the plaster surface even after two additional poultice applications.

The facing adhered with Acryloid B-67 took approximately two hours longer than the others to soften to a degree which allowed safe removal of the tissue. Even after eight hours, removal resulted in the loss of fragile layers. The surface remained extremely tacky, residue removal was difficult and for the most part, unsuccessful. Residue left on the surface remained unchanged after two additional poultice treatments. Some pigment was lost due to attempts to mechanically remove the adhesive. The plaster remained darkened with a uniform glossy surface film.

¹¹⁰ Colletta was made in bulk and stored following recommendations in Paolo and Laura Mora, Paul Phillipot, *The Conservation of Wall Paintings* (London: Butterworth's, 1984), 347.

¹¹¹ The acrylic resins took nearly twice as long as the colletta to hold the tissue in place.

Plextol B500:

The adhesive swelled but did not resolubilize after the application of solvents. Full-scale delamination of the plaster layer from the substrate occurred during attempts to remove the stiffened facings.

Vinamul 6825:

A methanol poultice facilitated removal of the Vinamul 6825 facing but a discontinuous residue remained, unacceptably darkening the surface of the plaster.

Polyvinyl alcohol (PVOH):

A 20% solution in water was less viscous than the acrylic resins and did not take as long to bond with the tissue facing. Removal of the polyvinyl alcohol facing adhesive was easily carried out by dabbing the surface with a cotton pad dipped in water and wrapped in gauze to prevent fibers from catching on irregularities in the surface texture of the panel. Clays swelled only minimally. No permanent deformation or delamination took place. Minor pigment loss occurred. The plaster was darkened very slightly but no adhesive film remained visible on the surface.

Of these treatments, the most successful was the polyvinyl alcohol adhesive. Facing and residue removal, easily accomplished using a poultice and water-soaked pads, resulted in only a slightly darkened surface. Negligible pigment and plaster loss occurred. *Colletta* treatment resulted in detachment of plasters from the substrate due to contraction of the glue. Although this condition made reversal of the facing adhesive more difficult

for these tests, it is the desired outcome when performing an actual detachment. Further testing using lower concentrations of the adhesive was indicated.



Fig. 36. Facing adhesive tests

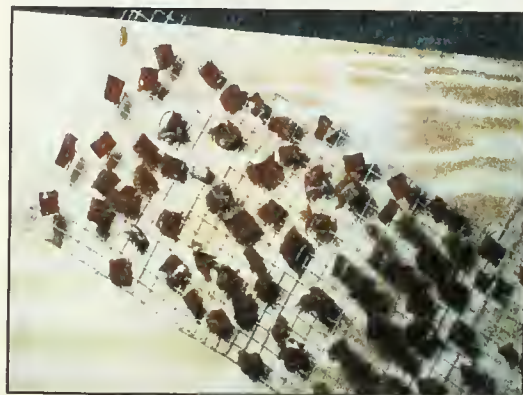


Fig. 37. Drying *colletta*



Fig. 38. Facing adhesive tests

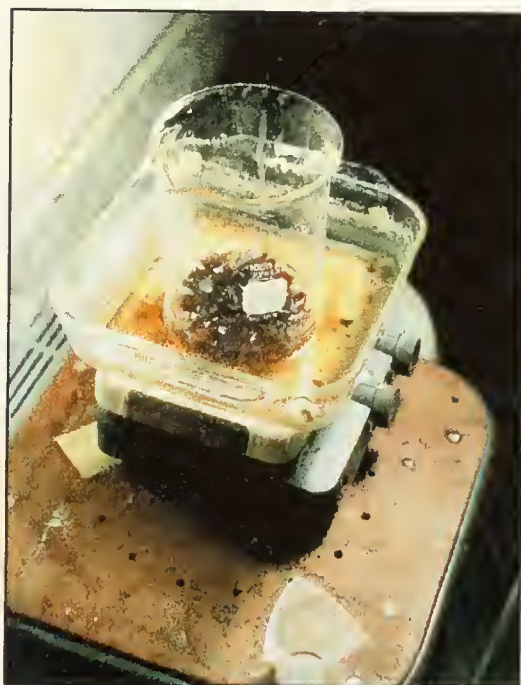


Fig. 39. Heating *colletta*



Fig. 40. Sample faced with *colletta* and Japanese tissue



Fig. 41. Sample faced with polyvinyl alcohol and Japanese tissue



Fig. 42. Sample faced with Acryloid B-67 and Japanese tissue



Fig. 43. Sample faced with Acryloid B-72 and Japanese tissue





Fig. 44. Appearance after removal of *colletta* facing



Fig. 45. Appearance after removal of polyvinyl alcohol facing



Fig. 46. Appearance after removal of Acryloid B-67 facing



Fig. 47. Appearance after removal of Acryloid B-72 facing



3.2.8 Test for Reattachment to New Support/Backing

Summary:

After a mural painting has been detached, it must be reattached to a stable new support.¹¹² Requirements of a new support are as follows:

- Preservation of the integrity of the original texture and form of the painted surface. The character of a painting is compromised when surface qualities are not retained.
- Materials similar enough in character to the painted layer to ensure that the two won't separate or sustain other types of damage due to changes in ambient temperature or humidity.
- Low thermal conductivity and capacity
- Resistance to moisture and changes in relative humidity. As the leading cause of deterioration in mural paintings, the introduction of moisture must be avoided through the application of an impermeable material.
- Lightweight, uncomplicated, reversible Resistance to solvents
- Resistance to ultraviolet light.
- Resistance to biological attack¹¹³

¹¹² For further information including traditional and modern methods for the reattachment of paintings to new supports, see *The Conservation of Wall Paintings*, Chapter 11, "Application to the New Support." Because this information refers to rigid supports of both traditional and synthetic materials and textile supports stretched on frames for the reattachment of fresco paintings on lime plaster, it is necessary to modify techniques and materials to meet the demands of earthen materials and the condition of the paintings.

⁸⁴ Paolo and Laura Mora and Paul Philipot, *The Conservation of Wall Paintings* (London: Butterworths, 1984) 262-265.

Attachment of *strappoed* murals to a new support required an immediate and simple solution in order to proceed with other tests, such as the removal of facing adhesives.

Although this aspect of work was not the focus of the research, a limited study was carried out to determine appropriate temporary supports.

Objective:

The aim was to cheaply and expediently determine methods and materials for adhering detached paintings to a new support while creating a bond strong enough to allow for facing and residue removal. It was important that the adhesive was a “contact” adhesive and did not penetrate into the mural painting. It was also important that the surface of the new support had a degree of cushion to accept the irregularities in the mural surface.

Methodology:

Twelve samples on gypsum board were detached with both *colletta* and polyvinyl alcohol facings. The backs of all the detached paintings were coated with two layers of 30% polyvinyl acetate emulsion to inhibit penetration of the backing adhesive. Several traditional reattachment techniques using a new lime plaster support were tried without success. They led to the development of alternate methods, also initially unsuccessful.¹¹⁴

¹¹⁴ Traditional supports made of slightly modified lime plaster have been used for the reattachment of frescos for centuries. A modified version of this type of support was tested for this research. Panels of ½” plywood were cut slightly larger than the samples to be detached. Two coats of 30% polyvinyl acetate emulsion (PVA) were applied to seal the surface of the panels. Grids of ½” metal lath were then stapled to the surface of each panel. The surface of each support was sprayed generously with water before the application of plaster. The lime plaster, consisting of one part slaked lime, two parts sand, and ⅛ part PVA emulsion was applied in a layer thick enough to cover the lath completely. Once the plaster became firm, it was sprayed again with water. Small slashes were made in the surface with a spatula and a second coat,

Time constraints required the researcher to examine temporary forms of support to advance to the next phase of research, facing removal.¹¹⁵ Temporary solutions included: reattachment to foam core supports using polyvinyl acetate emulsion brushed around the perimeters of the detached paintings; to plywood supports using Plasti-Tak® a kneadable, non-staining poster mount material; and finally, to foam core supports using Scotch Brand 3M Foam Tape.

Although this information only applies to laboratory tests, aspects of it may be useful for later phases of work. Data is summarized in Tables 17 and 18.

Observations:

Due to the inconsistent and often unacceptable results obtained from the reattachment of paintings to plaster supports, it was necessary to select a satisfactory temporary support.¹¹⁶ Modifications to these methods might have led to successful results,

about ¼ inch in depth was applied. At this time, one coat of PVA emulsion was applied to the back of the detached painting. When the second layer of plaster was firm but still impressionable, another coat of PVA was brushed on to the back of the paintings and they were then set in the mortar. Small sandbags were used to weight the surface of the paintings and the new supports were permitted to cure. Five samples, E-5, E-7, E-13, E-14, and E-15, were applied to this type of plaster. Three more samples, E-8, E-10, and E-11 were applied to plaster which had been modified by the addition of bentonite clay intended to increase the potential of forming a stable bond between the painting and the substrate by making the two more similar in character. Results of this program were unacceptable. Modifications to these methods might have led to successful results, but time constraints limited possibilities for further testing.

¹¹⁵ Data was required of all phases of testing prior to the beginning of the 1997 field season at Çatalhöyük.

¹¹⁶ Traditional lime plaster supports did not form stable bonds with the detached paintings. In every case, detached paintings attached only partially to the new supports. This instability caused significant deformation and loss during facing removal. Application of a water poultice causes swelling of the partially attached earthen plasters. Unsupported portions of the painting deform more erratically than those still attached. Facings and/or adhesive residue cannot be completely removed because there is no support for the painting. Samples from which the facings could be removed, exhibited permanent deformation when the clays swelled, deformed and dried, forming voids between the painting and the new support. Clay modified supports exhibited deep cracking in addition to the problem of partial bonding with the paintings.

but time constraints limited possibility for further testing. Additional research is recommended.

Attachment of the paintings to foam core supports by brushing PVA around their perimeters yielded widely inconsistent results, making it an unsatisfactory technique.¹¹⁷

Plasti-Tak and Scotch Brand Foam Tape provided both contact adhesive and cushion. It must be emphasized that neither of these materials is in any way meant to act as a conservation solution.¹¹⁸ Rather they were chosen to allow the researcher to proceed with testing for the compatibility of surface fixatives, preconsolidants, consolidants, and facing adhesives.¹¹⁹ Further research to develop an appropriate support for these plasters, although beyond the scope of this thesis, is recommended.

Although both temporary methods produced acceptable results, foam tape requires little pressure to adhere the thin painting layer to its substrate, significantly reducing the potential for damage during reattachment. It provided an economical and expedient solution to the problem.

¹¹⁷ The back of one of the paintings undergoing this treatment was overlaid with Plaster of Paris coated gauze strips for support and adhered to a foam core panel with PVA around its perimeter. Attempts to remove the facings resulted in total destruction of the plaster. Reattachment of a second painting using this method also failed. Only one painting treated with PVA around its perimeter exhibited favorable results. Facings and adhesive residue were removed easily and with minimal alteration to the surface appearance.

¹¹⁸ The removal of either of these adhesives would cause damage to the paintings.

¹¹⁹ Manageable pieces of Plasti-Tak were kneaded by hand and flattened onto the reverse of the paintings until they were covered with a thin uniform layer of adhesive. Paintings were then adhered to PVA emulsion-coated plywood panels and gently weighted with small sandbags to fully secure them. The Plasti-tak® was unaffected by both the water poultice and the application of steam used to remove the facings. Paintings showed little to no damage or loss. Surface appearances were virtually unaltered. Facings were removed easily, due in part to the secure bond between the paintings and the supports. Strips of foam tape covered the backs of the PVA emulsion-coated paintings. Paintings were easily transferred to a foam core panel. The water poultice and steam treatment used to remove facing materials did not affect the bond between the foam tape and the painting. Samples showed minimal deterioration, loss, or alteration of optical properties.



Fig. 48. Sample E4: PVA and foam core



Fig. 49. Sample E5: Plaster of Paris backing, PVA and foam core support



Fig. 50. Sample E6: PVA and foam core support

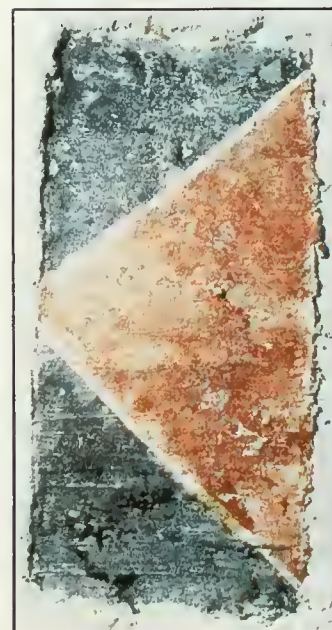


Fig. 51. Sample E7: Traditional plaster support



Fig. 52. Sample E8: Modified plaster support



Fig. 53. Sample E9: Plasti-tak support



Fig. 54. Sample E10: Modified plaster support



Fig. 55. Sample E11: Plaster support



Fig. 56. Sample E12: Foam tape

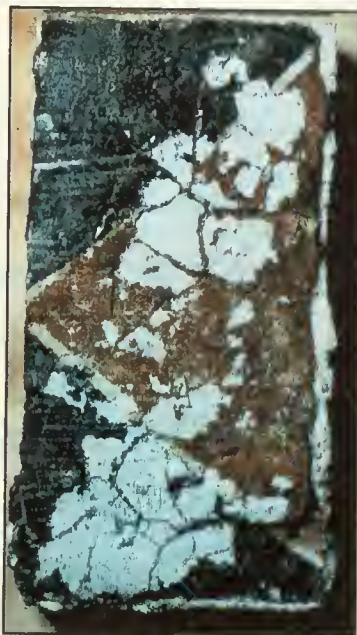


Fig. 57. Sample E13: Traditional plaster support

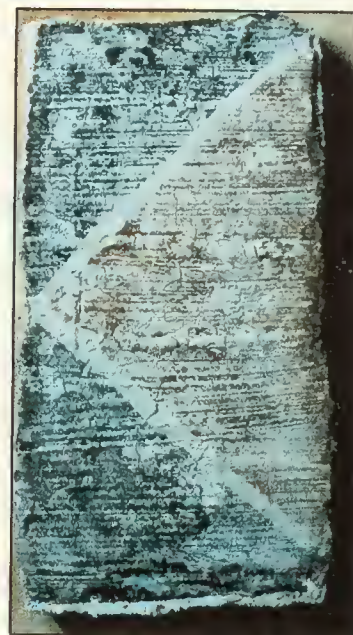


Fig. 58. Sample E15: Traditional plaster support



Fig. 59. Sample E14: Failed plaster support

3.2.9 Consolidation with Ethyl Silicates

Summary:

Field tests conducted in 1996 focused on the consolidation of earthen plaster and mudbrick with ethyl silicates. Based on laboratory research, the ethyl silicate monomer T-1919 was the most extensively tested. These silica esters are effective consolidants under certain conditions but do not function as adhesives in, for example, adhering detached layers. Therefore, if detachment has already occurred, pieces of mudbrick will not be held together.¹²⁰

The extreme friability of the plasters requires preconsolidation, a preliminary treatment that may also handle superficial delamination. To treat these conditions, two preconsolidants were tested, a 5% solution of Aquazol50 in ethanol in a 50/50 (v/v) mixture with the T-1919 monomer, and Acryloid B-72, in a 7% solution in xylene. The effects of the application of a single preconsolidant followed by the application of a consolidant as well as the effects of the application of both preconsolidants followed by the application of a consolidant were observed. Treatments that demonstrated significant strengthening of the plaster, exhibited unacceptable levels of discoloration. Treatments that caused only slight discoloration did not substantially increase the strength of the plaster.¹²¹

¹²⁰ For further discussion see, Alejandro Alva Balderrama and Giacomo Chiari, "Protection and Conservation of Excavated Structures of Mudbrick" in *Conservation on Archaeological Excavations With Particular Reference to the Mediterranean Area* (Rome: ICCROM, 1984), 114.

¹²¹ Sections preconsolidated with the Aquazol 50/T-1919 mixture (one spray application) and either a brush or spray application of Acryloid B-72 (7% in xylene), then consolidated with T-1919 (3cycles/day for 5 days, spray applied) were strengthened but darkened significantly. The section preconsolidated with the

Although field results were unremarkable, laboratory tests carried out at the Architectural Conservation Laboratory and at other earthen architecture sites have demonstrated the effectiveness of ethyl silicates.¹²² It is believed that a relative humidity of 50% to 75% promotes curing of ethyl silicates. Extremely low humidity on site may account for the lack of significant improvement during field tests. Further research in situ is required to fully test these materials.

Objective:

In order to consider ethyl silicate consolidation of the samples in the research program, two of the eight prototype samples, G and J, were consolidated with T-1919. Based on previous fieldwork, one sample was first preconsolidated with a 50/50 mixture

Aquazol50/T-1919 mixture (one spray application) followed by a brush application of Aquazol 50 (5% in ethanol), then consolidated with T-1919 (3cycles/day for 5 days, spray applied) was strengthened but darkened significantly. The section preconsolidated with Acryloid B-72 (7% in xylene, brushed on), then consolidated with T-1919 (3cycles/day for 5 days, spray applied) was strengthened, but darkened significantly. Sections preconsolidated with the Aquazol50/T-1919 mixture (one spray application), then consolidated with T-1919 (3cycles/day for 5 days, spray applied), were only negligibly strengthened and slightly darkened. The section consolidated with T-1919 (3cycles/day for 5 days, spray applied) only, was negligibly strengthened, exhibited no color change, and lost more detaching plaster than sections which had been preconsolidated. A full report of the treatments and results of this program can be found in Evan Kopelson, "Analysis and Consolidation of Architectural Plasters from Çatalhöyük, Turkey" (masters thesis, University of Pennsylvania, 1996) 112-129.

¹²² For additional information, see Giacomo Chiari, "The Treatment of Adobe Friezes in Peru" and Paul M. Schwartzbaum, Constance S. Silver, and Christopher Wheatley, "The Conservation of a Chalcolithic Mural Painting on Mud Brick from the Site of Teleilat Ghassul, Jordan," in *Third International Symposium on Mudbrick (Adobe) Preservation*, edited by Okan Üstünkök and Emre Madran (Ankara: ICOM/ICOMOS, 1980); Ricardo Morales Gamarra, "Conservation of Structures and Decorative Adobe Elements in Chan Chan," *Adobe: International Symposium and Training Workshop on the Conservation of Adobe. Final Report and Major Papers. Lima-Cusco (Peru). 10-22/September 1983*, (Rome: ICCROM, 1983) 83-89; and Constance S. Silver, "Analyses and Conservation of Pueblo Architectural Finishes in the American Southwest," *6th International Conference on the Conservation of Earthen Architecture: Adobe 90 Preprints*, (Los Angeles: The Getty Conservation Institute, 1990) 176-181.

of Aquazol 50® (5% in ethanol) / T-1919. Both were then consolidated using the T-1919 monomer at full strength.¹²³

Description of Materials

Aquazol 50®, poly (2-ethyl-2-oxazoline), or PEOX, is a non-ionic polymer adhesive that is highly soluble in water as well as a range of polar organic solvents such as acetone, dimethyl formamide, ethanol, methanol, methylene chloride, and methyl ethyl ketone.¹²⁴ It is mechanically and thermally stable and it remains stable in weak acids and bases. It is compatible with other polymeric materials and is heat-sealable. Accelerated light aging tests did not alter its appearance, ease of handling, or resolubilization.¹²⁵ Films of this polymer remain plastic even in low relative humidity environments such as that of Çatalhöyük. Because this product is relatively new, and has not been tested in the field, it will not necessarily be recommended.

T-1919 Conservare OH ® Stone Strengtheners, or tetraethylorthosilicate, an ethyl silicate monomer, demonstrated the most promise in previous laboratory testing. This system is based on silicic ethyl esters, which have an extremely small molecular structure,

¹²³ These treatments were the most successful of those carried out in the 1996 field season developed by Constance Silver.

¹²⁴ Aquazol 50® is an adhesive produced by Polymer Chemistry Innovations by license from the Dow Chemical Company.

¹²⁵ Test results indicate that Aquazol 50® drops in molecular weight and decreases in size rather than cross-linking or increasing in size under aging conditions. After undergoing the equivalent of twenty four years of natural aging, the polymer will resolubilize in the same solvents it was initially soluble in. Tests of its adhesive capabilities for conservation applications were conducted at the Analytical Department of the Winterthur Museum. Results of the tests focused on four working characteristics: "ability to flow and penetrate, ability to relax flakes, overall security on drying, and visual effects on surrounding design materials." Data was favorable. The positive results of these tests were based on the treatment of painted wooden indoor objects. Further study is required to determine the long-term effects of this adhesive on

allowing for deep penetration into the earthen plasters by capillary action while retaining the original porosity of the surface. As it cures, the silicic ester gel transforms into silica oxide, a mineral compatible with the earthen plaster. The silica oxide reacts with the clay particles to form a tri-dimensional network of silica bridges, increasing the water resistance of the material.¹²⁶ The viscosity of this consolidant, which is lower than that of water, permits the binding of even minute particles. As previously indicated, low relative humidities may have hindered the reaction of the ethyl silicate monomer at the site. The performance of consolidation treatments in the field may be improved by covering the treated sections in a manner similar to the method used to retard drying time of the plasters during facsimile development.

Methodology

Both the preconsolidant and ethyl silicate monomer systems were applied to Sample G. The 50/50 (v/v) Aquazol 50(5% in ethanol)/T-1919 mixture was sprayed on in one application immediately prior to application of the consolidant. Sample J was treated with only the consolidant.¹²⁷ T-1919 was brushed directly on to the surface of both panels. Three applications at 30 minutes apart were applied daily. Each application consisted of three saturating applications of consolidant five minutes apart. The process was repeated at the same time every day for five days. The sample was then permitted to cure for approximately one month prior to additional treatment.

exposed, expansive earthen plaster walls. Richard C. Wolbers, Mary McGinn, and Deborah Duerbeck, "Poly (2-ethyl-2-oxazoline): A New Conservation Adhesive" (n.p., n.d.).

¹²⁶ Balderrama and Chiari, 114.

Observations:

The depth of penetration and effects of the consolidants on the plaster samples were measured using the Iodine Vapor Test: Determining the Depth of Penetration of Consolidants; the CRATerre Water Drop Test; and ASTM D3359-90: Measuring Adhesion by Tape Test (Methods A and B). These tests are described in Section 3.3, “Evaluation of Preliminary Testing A.” Based on simple visual assessment, a minimal alteration of optical properties occurred after consolidation.

¹²⁷ Both samples had been sprayed with a 3% solution of B-72 in toluene prior to consolidation in order to help stabilize the surface.

3.3 Evaluation of Preliminary Testing A

In order to select materials for the final testing program, treatments were evaluated using the following standardized tests by the American Society for Testing and Materials (ASTM), CRATerre, and the Federation of Societies for Coatings Technology: ASTM D 4214-89 “Evaluating the Degree of Chalking of Exterior Paints” and ASTM D3359-90 “Measuring Adhesion by Tape Test,” “The Iodine Vapor Test: Determining the Depth of Penetration of Consolidants,” and the CRATerre Water Drop Test. These tests facilitated the assessment of materials in treating friable, powdery paint and/or plaster, reestablishing adhesion between detached pieces or layers, improving adhesive and cohesive properties of the paint and plaster layers, and penetrating the paint and plaster (for assessment of the consolidants). The techniques were accessible, affordable and allowed for visually quantifiable and qualifiable results. The performance of the materials and methods were visually examined and quantitatively assessed. The performance of each treatment informed the final testing program.

3.3.1 ASTM D4214-89: Evaluating the Degree of Chalking of Exterior Paint Films

Summary:

ASTM defines chalking as the formation on a pigmented coating of a friable powder evolved from the film itself at or just beneath the surface.¹²⁸ A friable, powdery paint or plaster layer will transfer this residue to fabric that is swiped across its surface. The test provides a method for evaluating the degree of chalking transferred to fabric or to a finger through comparison to photographic reference standards.

Objective:

The aim of this test was to assess the effectiveness of treatments based on the degree of chalking exhibited by treated and untreated samples.

Methodology:

Tests were carried out on four multi-layer painted samples on terra cotta supports following the procedures specified in D4214-89 Section 7 for wood substrates, Methods A and B.

<u>Sample</u>	<u>Treatment</u>
UT:	Untreated
B-72:	Surface consolidated with Acryloid B-72 (3% in toluene) x 8
ES:	Consolidated with ethyl silicate monomer T-1919
AQES:	Preconsolidated with a 50/50 (v/v) mixture of Aquazol 50 (5% in ethanol) / T-1919, then consolidated with T-1919

¹²⁸ ASTM, "ASTM D4214-89: Evaluating the Degree of Chalking of Exterior Paint Films," in *1990 Annual Book of ASTM Standards Section 6: Paints, Related Coatings and Aromatics* (Philadelphia: ASTM, 1990), 70-71.

Method A:

A swatch of black velvet wrapped around an index finger is applied to the surface of the sample with medium pressure. The finger is then rotated at an angle of approximately 180°. The chalk mark left on the fabric is then compared to Photographic Reference Standard #1 in the *Pictorial Standards of Coatings Defects*.

Method B:

A swatch of black velvet wrapped around the index finger is stroked with medium pressure across the surface of the sample for approximately three inches. The chalk mark left on the fabric is compared to Photographic Reference Standard #1 in the *Pictorial Standards of Coatings Defects*.

Results are shown in Figures 60 and 67 and Table 19.

Observations:

All of the treated samples exhibited a visually appreciable improvement in chalking resistance when compared to photographic reference standards and with the test results of an untreated sample. No significant differences in resistance were detected between the treated samples. All merited a rating of 8 on the ASTM reference scale.



Fig. 60. Chalking Test Method A: Untreated



Fig. 61. Chalking Test Method A: Surface consolidated with Acryloid B-72 (3% in toluene) x 8



Fig. 62. Chalking Test Method A:
Consolidated with ethyl silicate monomer
T-1919



Fig. 63. Chalking Test Method A:
Preconsolidated with 50/50 mixture of
Aquazol 50(5% in ethanol)/T-1919
Consolidated with T-1919



Fig. 64 Chalking Test (Method B):
Untreated



Fig. 65 Chalking Test (Method B): Surface
consolidated. Acryloid B-72
(3% in toluene) x 8



Fig. 66 Chalking test (Method B):
Consolidated with T-1919



Fig. 67 Chalking test (Method B):
Preconsolidated with 50/50 mixture of
Aquazol 50(5% in ethanol)/T-1919
Consolidated with T-1919

3.3.2 ASTM D 3359-90: Measuring Adhesion by Tape Test (Methods A and B)

Summary:

Aims of the preliminary testing program included the reestablishment of adhesion between detached layers, stabilization of the painted plaster surface, and improvement of the adhesive and cohesive properties of the paint and plaster layers. Tests designed to evaluate the adhesion of coating films to metallic substrates were modified to evaluate the performance of various conservation materials meant to increase the adhesive properties of the paint and plaster layers.¹²⁹

Objective:

This test was intended to supplement treatment assessment by comparing the adhesive properties of treated and untreated samples.

Methodology:

Tests were carried out on four multi-layer painted samples on terra cotta supports.

<u>Sample</u>	<u>Treatment</u>
UT:	Untreated
B-72:	Surface consolidated with Acryloid B-72 (3% in toluene) x 8
ES:	Consolidated with ethyl silicate monomer T-1919
AQES:	Preconsolidated with a 50/50 (v/v) mixture of Aquazol 50 (5% in ethanol) / T-1919, then consolidated with T-1919

ASTM 3359-90 Test Method A: An X-cut was made on the surface of the samples with a scalpel (each line measuring approximately 40 mm). A three-inch section of one-

¹²⁹ ASTM, "ASTM D 3359-90: Measuring Adhesion by Tape Test (Methods A and B)" in *1990 Annual Book of ASTM Standards Section 6: Paints, Related Coatings and Aromatics* (Philadelphia: ASTM, 1990), 511-517.

inch wide semi-transparent, pressure sensitive tape was smoothed over the incisions and pressed with the eraser tip of a pencil. The tape was removed before ninety seconds had passed at as close to a 180° angle as possible. Adhesion was rated based on a standardized scale. Two X-cuts were made on each sample, one superficial, (A.1) and one penetrating (A.2).

ASTM 3359-90 Test Method B: The procedure described in ASTM D 3359-90, Test Method B was slightly modified due to the fragility of the plasters. Samples were placed on a stable horizontal surface. Eight parallel cuts approximately one inch long, were made with an X-acto knife at $\frac{1}{8}$ -inch intervals. Each cut was made in one steady motion using medium pressure. Once all the cuts were made, the surface was brushed lightly to remove any detached flakes or dust. Eight more cuts were then made the same distance apart at right angles to the originals, forming a lattice. The surface was again brushed lightly, taking care not to detach the fragile plaster layers. A three-inch strip of pressure sensitive tape was applied to the center of the grid and smoothed with a finger. After approximately forty-five seconds, the tape was removed at as close to a 180° angle from the surface of the sample as possible. The grid was then inspected for coating loss and adhesion was rated on the following scale. (Test Method B.2) The entire procedure was repeated with the same number of cuts made at five-millimeter intervals. (Test Method B.2)

Ratings were evaluated based on the ASTM scale and combined in Tables 20 and 21 with the test results.

Observations:

Test Method A

Tests performed on the untreated sample caused the most overall damage. Treated samples showed an appreciable strengthening of the surface as compared to the untreated sample. All of the samples exhibited significant damage after the deeper incision.¹³⁰ The sample consolidated with T-1919 showed the best results.

Observations:

Test Method B

All of the treated samples showed an appreciable improvement in surface stability when compared to the untreated samples. The sample consolidated with the ethyl silicate monomer, T-1919 produced the best results. Those consolidated with eight applications of Acryloid B-72 (3% in toluene) produced the next best results.

¹³⁰ This ASTM test, designed to assess the adhesion of coating films applied to metallic substrates, requires that incisions be cut down to the substrate. The amount of pressure required to make that type of incision caused the destruction of this coating. The process was modified so that incisions penetrated only the outermost four to five layers.



Fig. 68. Measuring Adhesion by Tape Test (Method A): Untreated

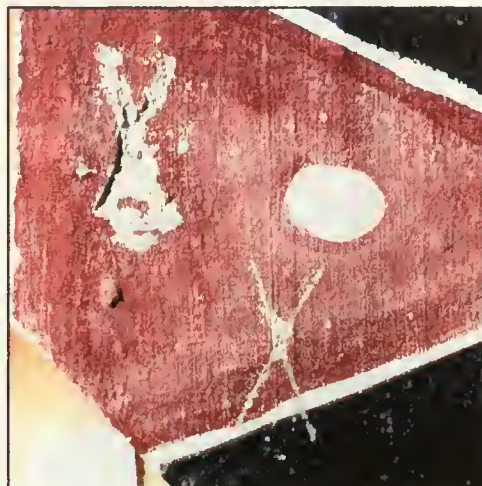


Fig. 69. Measuring Adhesion by Tape Test (Method A): Surface consolidated with Acryloid B-72 (3% in toluene) x 8



Fig. 70. Measuring Adhesion by Tape Test (Method A): Consolidated with T-1919



Fig. 71. Measuring Adhesion by Tape Test (Method A): Preconsolidated with 50/50 mixture of Aquazol 50 (5% in ethanol)/T-1919 Consolidated with T-1919

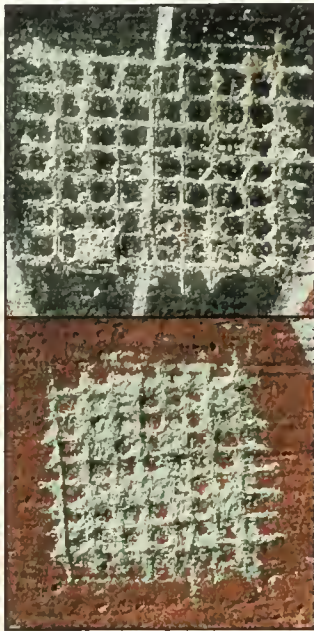


Fig. 72. Measuring Adhesion by Tape Test
(Method B): Untreated



Fig. 73. Measuring Adhesion by Tape Test
(Method B): Surface Consolidated with
Acryloid B-72 (3% in toluene) x 8



Fig. 74. Measuring Adhesion by Tape Test
(Method B): Consolidated with T-1919

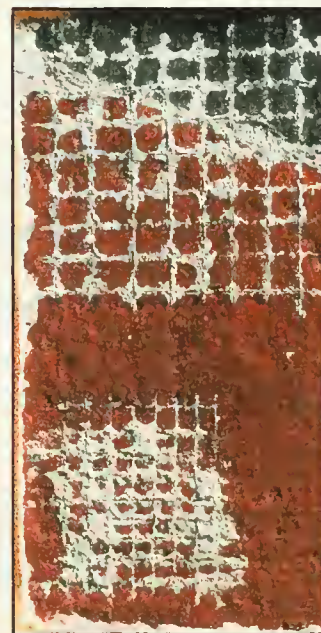


Fig. 75. Measuring Adhesion by Tape Test
(Method B): Preconsolidated with 50/50
mixture of Aquazol 50
(5% in ethanol)/T-1919
Consolidated with T-1919

3.3.3 Determining Depth of Penetration of Consolidants: Iodine Vapor Test

Summary:

It is critical to test the depth of penetration of consolidants into a material prior to full-scale treatment. Problems often arise when consolidated and unconsolidated zones are created within a single substrate. These zones contract and expand at different rates and may undergo considerable stress at their interface, resulting in the loss of surface material. An accumulation of moisture and salts behind this interface may cause further deterioration of the mudbrick or plaster.¹³¹ Pre-testing of consolidated sample material accommodates modification of materials and methods prior to on-site treatment.

Objective:

The purpose of this procedure was to determine the distribution and depth of penetration of consolidants applied to the prototype samples.¹³²

Methodology:

Approximately forty grams of iodine crystals were divided between two glass containers and placed in a lidded glass chamber.¹³³ Three treated multi-layer plaster samples were placed in the chamber and observed at ten-minute intervals for approximately two hours. The vapor given off by the iodine crystals physically adsorbs

¹³¹ This occurrence was also noted during the 1960's mural painting treatments at Çatalhöyük. See Pamela French, "The Problems of In Situ Conservation of Mudbrick and Mud Plaster" in *In Situ Archaeological Conservation, Proceedings of meetings, April 6-13, Mexico* (Mexico: Instituto Nacional de Antropología e Historia, 1987; California: J. Paul Getty Trust, 1987), 81.

¹³² Rakesh Kumar and William S. Ginell, "A New Technique for Determining the Depth of Penetration of Consolidants into Limestone Using Iodine Vapor," in *Journal of the American Institute for Conservation*, Volume 36, No. 2 (Summer 1997): 143-150.

¹³³ The crystals were left to sit uncovered until the chamber filled with iodine vapor.

onto the surface of organic compounds resulting in a yellow to light brown stain. The first sample, (ES-1) had been cut from the prototype consolidated with the ethyl silicate monomer T-1919. The second sample, (AQES-1) had been cut from the prototype pre-consolidated with the 50/50 mixture of Aquazol 50 (5% in ethanol) / T-1919 and consolidated with T-1919. The third sample, (B72) had been sprayed with eight applications of Acryloid B-72 (3% in toluene).

Observations:

Minimal changes were observed during the first hour of testing but each of the samples exhibited maximum staining after approximately two hours.¹³⁴ The plaster and the terra cotta surfaces of the ethyl silicate treated samples exhibited a deep pinkish yellow color. Although staining is observed throughout the samples, the blotchy appearance indicates irregular distribution. The surface of the sample treated with Acryloid B-72 exhibited an orange-yellow stain that did not penetrate the sample.

¹³⁴ Sufficient vapor may not yet have accumulated in the chamber before the samples were introduced.



Fig. 76 . Iodine Vapor Test: Determining the Depth of Penetration of Consolidants. (Left) Sample consolidated with ethyl silicate monomer T-1919. (Right) Sample preconsolidated with 50/50 mixture of Aquazol50(5% in ethanol)/T-1919, then consolidated with T-1919.

3.3.4 Water Drop Test: CRATerre

Summary:

In order to evaluate the resistance to water of treated and untreated plasters, a test was performed in which samples are subjected to the continuous impact of water droplets for a period of one to two hours or until the sample has been penetrated. Deterioration of the paint and plaster is monitored and recorded throughout the test, permitting evaluation by measurement of visually appreciable results.

Objective:

The purpose of this test was to assess the effects of the preconsolidation and consolidation treatments on the resistance to water of two types of treated samples. Test results were then compared to those of the untreated samples.

Methodology:

Two samples each of untreated, consolidated, and preconsolidated and consolidated samples were tested based on a method developed by CRATerre to determine the effectiveness of impregnating treatments. The surface of each sample was submitted to the impact of continuous droplets of water to a single spot, at a rate of one per second from a height of 2.5 meters, for a period of two hours. Samples were monitored continuously and effects were evaluated every ten minutes. Results are listed in Tables 22-27.

Observations:

Differences between the untreated and treated samples were significant. Minimal deterioration occurred in all the samples during the first hour of testing. Shortly into the second hour, the untreated samples began to exhibit extensive losses of both paint and plaster. One of the ethyl silicate consolidated samples, (ES-1), exhibited a slight loss of pigment and plaster due to an anomaly within the plaster layer. The water drop was centered on a preexisting deformation that masked a void in the plaster. Losses of the preconsolidated and consolidated samples were minimal compared to those of the untreated plaster.



Fig. 77. Preparation for water drop test.

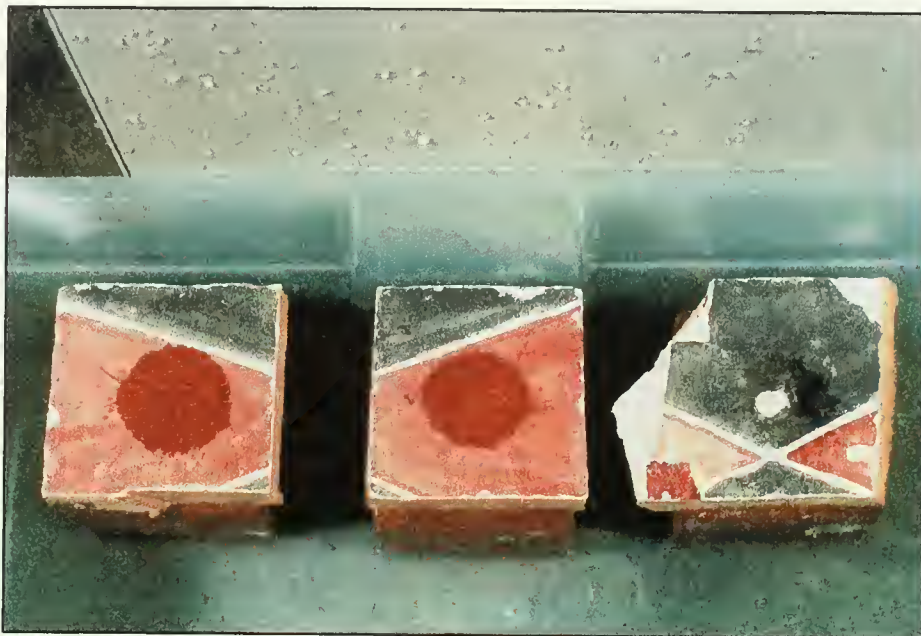


Fig. 78 Water drop test after 10 seconds: (Left to right) Untreated (UT1), Untreated (UT2), Ethyl silicate (ES1)



Fig. 79. Water drop test after 2 hours: (Left to right) UT1, UT2, ES1

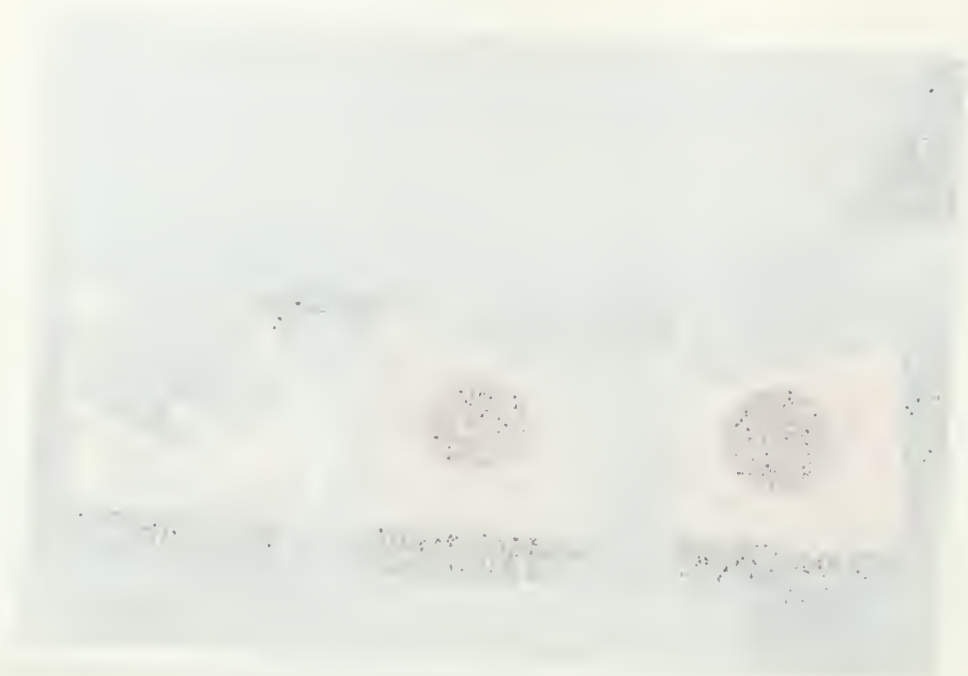




Fig. 80. Water drop test after 10 seconds: (Left to right) Aquazol50/T-1919+T-1919 (AQES1), Aquazol50/T-1919+T-1919 (AQES2), Ethyl silicate (ES2)



Fig. 81. Water drop test after 2 hours: (Left to right) Aquazol50/T-1919+T-1919 (AQES1), Aquazol50/T-1919+T-1919 (AQES2), Ethyl silicate (ES2)

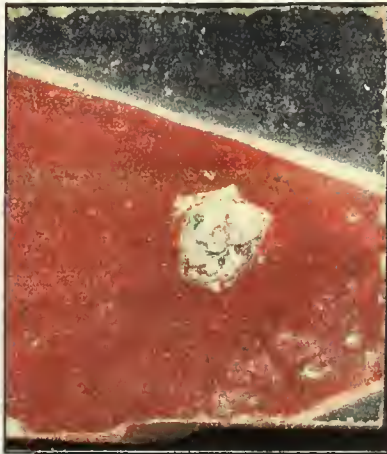


Fig. 82. Water drop test final result:
UT1



Fig. 83. Water drop test final result:
UT2



Fig. 84. Water drop test final result:
ES1

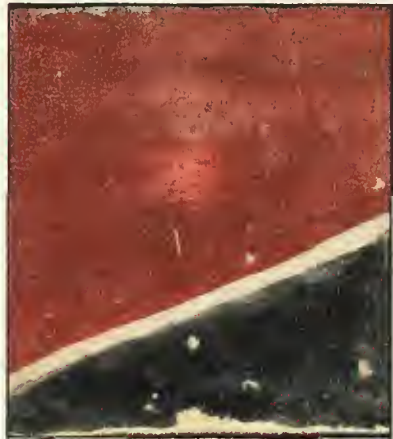


Fig. 85. Water drop test final result:
ES2



Fig. 86. Water drop test final result:
AQES1



Fig. 87. Water drop test final result:
AQES2

3.4 Preliminary Testing B: Compatibility of Treatments

Summary:

The purpose of “Preliminary Testing A” was to evaluate materials and methods to treat the following individual conditions: powdering paint, interlayer detachment, and cleavage of the surface layer. The program then addressed the detachment of mural paintings by testing both traditional and non-traditional facing adhesives for *strappo* and *stacco*. Compatible materials were chosen for all aspects of treatment.

For this aspect of research, it was necessary to identify the appropriate facing adhesive based on the following characteristics:

- Adequate adhesion over all the painted surface to permit detachment at a consistent level, whether that be *stacco*, removal of all the layers; or *strappo*, removal of only the top layer.
- Compatibility with pretreatment, for example, soluble in different solvents than those required for pretreatment materials.
- Reversibility.

A combination of conservation treatments is usually required to treat painted earthen plasters following excavation. The next phase of research, “Preliminary Testing B,” addressed the compatibility of these treatments. Results served to inform the final testing program.

The problem of consolidation of the paint layer was addressed first. This aspect of treatment aimed to stabilize the powdering/chalking paint layer so that other aspects of

treatment could be conducted. A surface consolidant was required to accomplish this without altering the optical properties of the samples and without interfering with other aspects of treatment. Thus, it needed to affect the surface without penetrating it and still be thin enough not to prevent the penetration of subsequent treatment materials. Since aqueous materials were to be used in most other aspects of treatment, it was particularly important that the surface consolidant was not soluble in water. Several materials were tested. The most effective were: Acryloid B-72 in a 3% solution in xylene, and, based on previous tests, Blair Spray Fix, a nitro-cellulose-based surface fixative developed for the treatment of pastels and temperas.¹³⁵

The next phase of testing focused on preconsolidation. The use of aqueous materials, which swell the clays, may facilitate readhesion when controlled. Results of preliminary testing indicated that a softened, swelled plaster surface might be flattened by applying pressure over Mylar. This treatment aids in compacting and readhering cracked pieces, improving craquelure, and relaxing cleavage. Both water, and water followed by Aquazol 50 (5% in water) were successful as preconsolidants during preliminary testing.

Finally, four traditional and non-traditional, or synthetic facing adhesives were tested in conjunction with other aspects of treatment. They were: *colletta*, polyvinyl alcohol, Plextol B500, and Vinamul 6825. These adhesives were assessed based on ease

¹³⁵ Constance S. Silver successfully employed Blair Spray Fix for tests to detach earthen plaster murals at Mesa Verde. The program is described in "Architectural Finishes of the Prehistoric Southwest: A Study of the Cultural Resource and Prospects for its Conservation" (Master's Thesis, Columbia University, 1987) 176. Because nitrocellulose darkens considerably with age, the material was not used for the final testing program here.

of detachment, ease of facing removal, preservation of optical properties, and compatibility with prior treatment.

Objective:

The purpose of this investigation was to evaluate the compatibility of treatments based on the following criteria:

- Preservation of original appearance in terms of: color, gloss, texture, and surface form
- Success at achieving the objective: efficient detachment of the plaster stratum as a whole or of a discreet layer
- Successful reattachment of the painting to a new support
- Removal of the facing adhesive with little or no damage to the painted plaster surface

Materials were selected based on their performance, stability (as observed in previous testing) and retrievability.

Methodology:

Various combinations of surface fixatives, preconsolidants and facing adhesives were applied to sixteen 6-by-6-inch multi-layer, painted gypsum wallboard panels in order to evaluate their compatibility. Detachments were carried out using traditional and modern materials. The details of each test are listed in Tables 28-31.

Observations:

Both *colletta* and polyvinyl alcohol successfully met facing adhesive criteria:

- Does not penetrate the surface of the plaster
- Facilitates detachment
- Provides support to detached plaster layer
- Permits easy removal of the facings and residue
- Are not adversely affected by other forms of treatment

Colletta:

Results of tests combining *colletta* facings with other aspects of treatment were generally positive. Although the *strappo* technique is designed to detach the paint layer alone, both the *stacco* and *strappo* formulas yielded *stacco*-like results in preliminary testing. Contraction of the *strappo* glue caused nearly complete detachment of the plaster stratum without mechanical intervention. The *strappo* facing is generally easier to remove, particularly when the water poultice technique is used in conjunction with steam.¹³⁶ A slight yellow residue often remained on the surface of the samples.¹³⁷

Polyvinyl alcohol:

Polyvinyl alcohol facings were easily removed. The adhesive resolubilized quickly with water poultices without affecting the plaster and paint layers. Detachment of

¹³⁶ Differences in the ease of removal of these two facings may be due to a number of circumstances. The *stacco* method includes a plasticizer in the *colletta* recipe, the *strappo* method does not. The *stacco* method requires that the first facing be dry before the application of the second, while in *strappo*, the two layers are applied consecutively. The greater tenacity of the *stacco* facing may be due in part to the additional coat of glue used to adhere the secondary facing after the first has dried.

¹³⁷ This may be due in part to the inexperience of the researcher.

the full plaster stratum was achieved easily with few losses and negligible darkening.¹³⁸

Based on ease of application and removal, and the preservation of appearance, polyvinyl alcohol was found to be the most effective facing adhesive.

Plextol B-500 and Vinamul 6825:

Plaster surfaces had to be flooded with solvents before tissue facings attached with Plextol B-500 and Vinamul 6825 could be removed. Textile facings could be removed only with significant force, if at all. Dilute solutions of these adhesives were no less tenacious. Plextol B-500 and Vinamul 6825 were ruled out as facing adhesives based on the results of the preliminary testing program.

¹³⁸ This may have been due in part to a weak bond between the plasters and gypsum board substrate.



Fig. 88. Studio overview showing preliminary test samples.



Fig. 89. Test materials



Fig. 90. Secondary facing removal

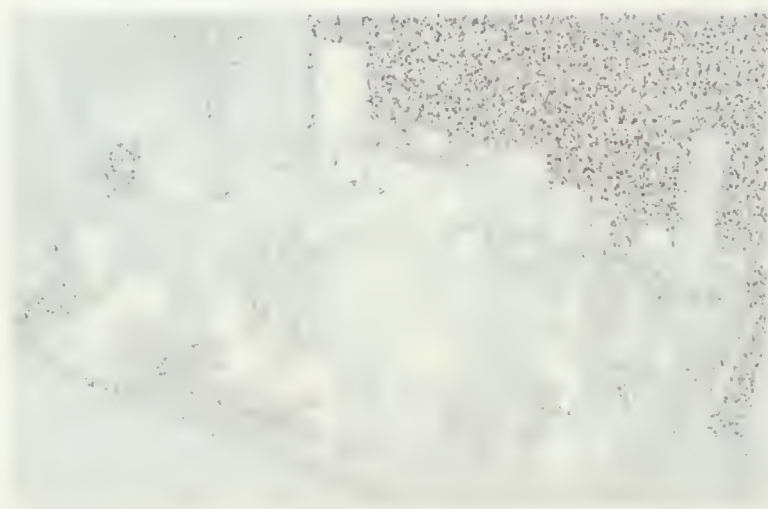




Fig. 91. Compatibility of Treatments: (Left) Untreated (Right) Sample D-1 after detachment with *stacco colletta*.



Fig. 92. Compatibility of Treatments: (Left) Untreated (Right) Sample D-2 after detachment with *strappo colletta*.

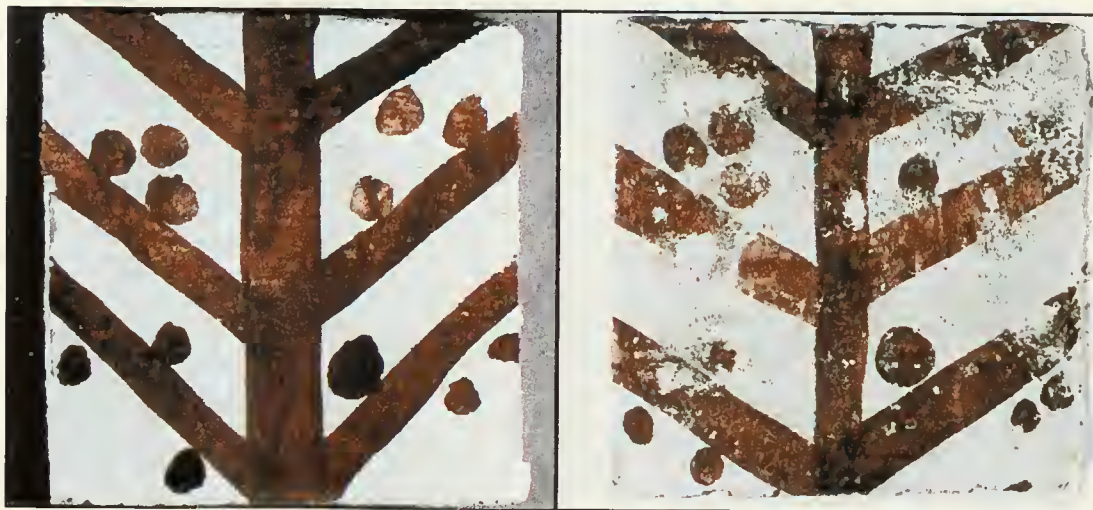


Fig. 93. Compatibility of Treatments: (Left) Untreated (Right) Sample D-3 after detachment with *strappo colletta*.

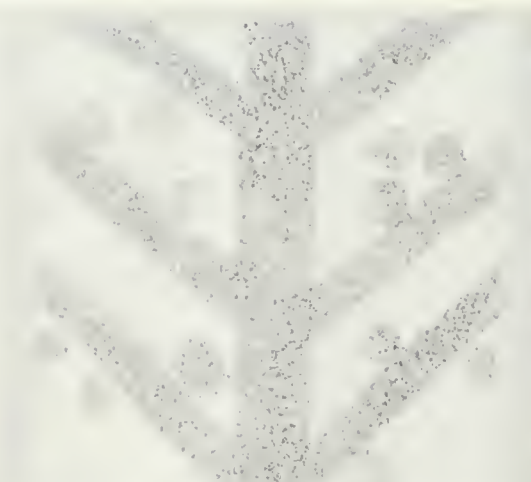
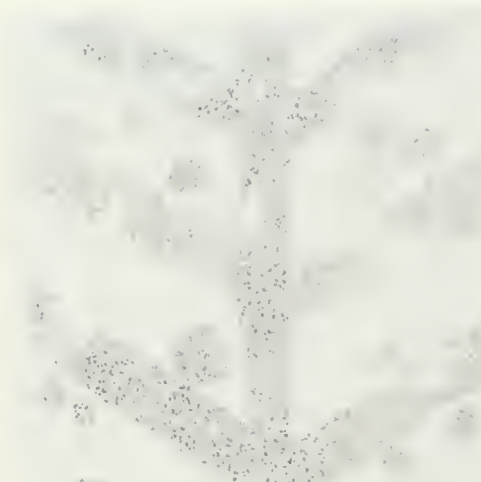
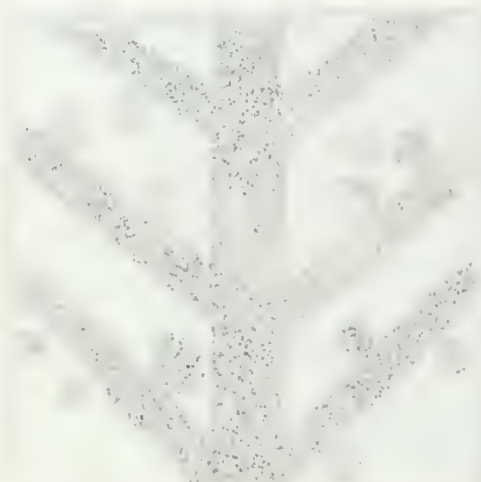
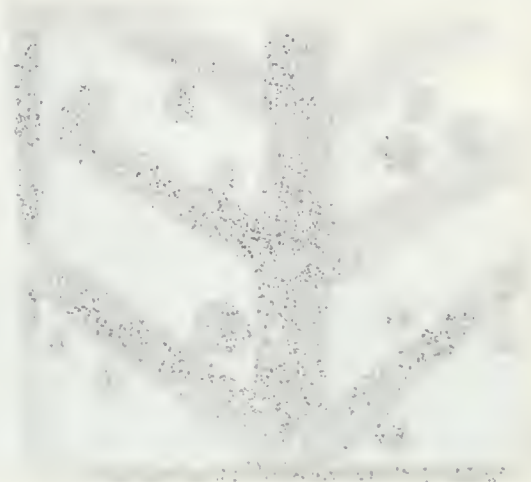
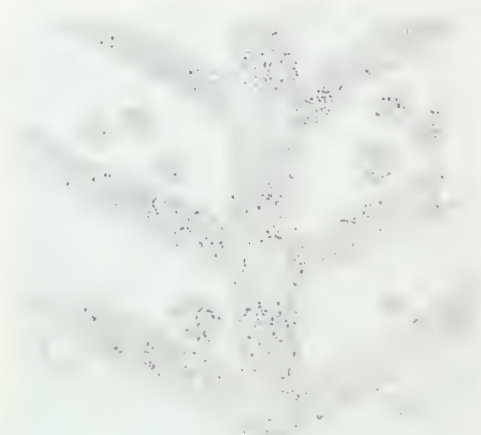




Fig. 94. Compatibility of Treatments: (Left) Sample D-4 after detachment with *stacco colletta* (Right) Untreated



Fig. 95. Compatibility of Treatments: (Left) Sample D-5 after detachment with PVOH (Right) Untreated



Fig. 96. Compatibility of Treatments: (Left) Sample D-6 after detachment with PVOH (Right) Untreated

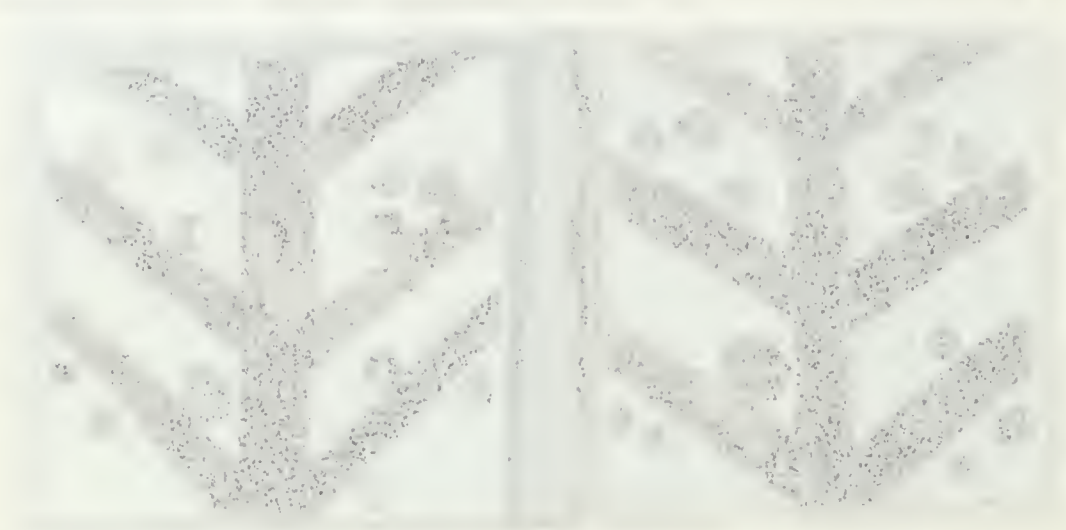




Fig. 97. Compatibility of Treatments: (Left) Untreated (Right) Sample D-7 failed detachment with Plextol B500 facing.



Fig. 98. Compatibility of Treatments: (Left) Untreated (Right) Sample D-8 after detachment with Vinamul 6825 facing.



Fig. 99. Compatibility of Treatments: (Left) Untreated (Right) Sample D-9 failed detachment with Plextol B500 facing.

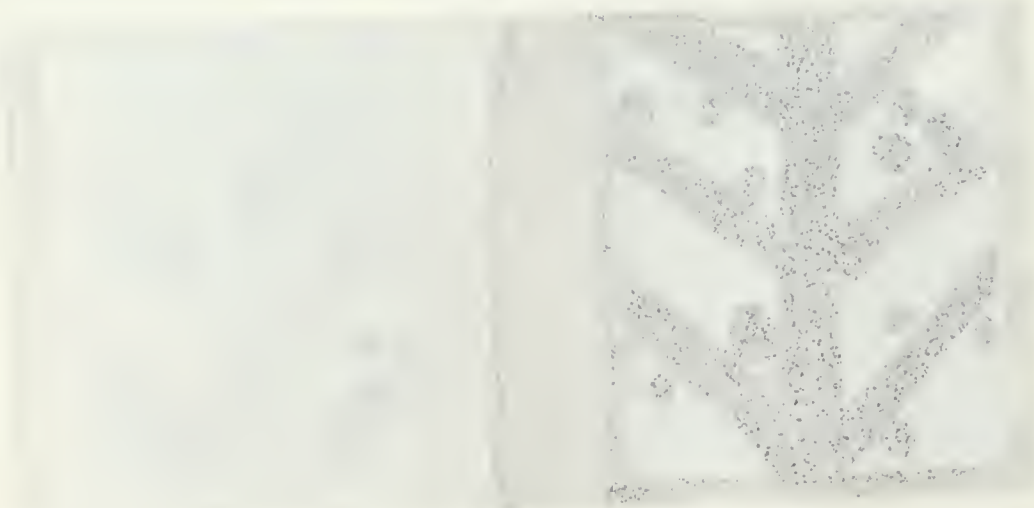




Fig. 100. Compatibility of Treatments: (Left) Untreated (Right) Sample D-10 after detachment with Vinamul 6825



Fig. 101. Compatibility of Treatments: (Left) Untreated (Right) Sample D-12 after detachment with PVOH

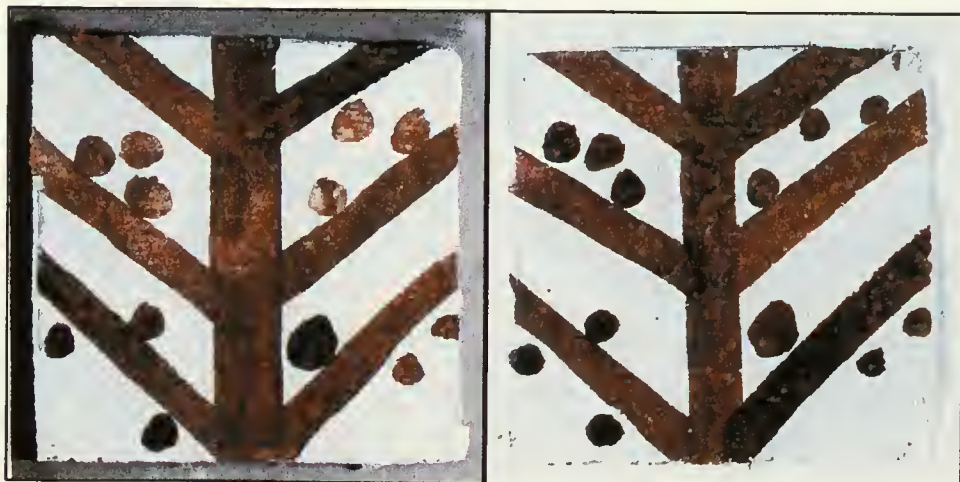


Fig.102. Compatibility of Treatments: (Left) Untreated (Right) Sample D-17 after detachment with PVOH

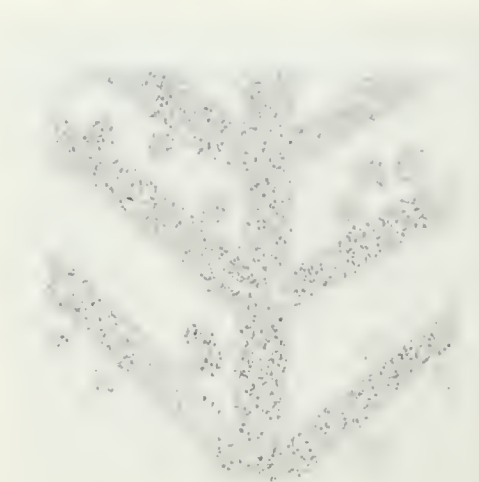




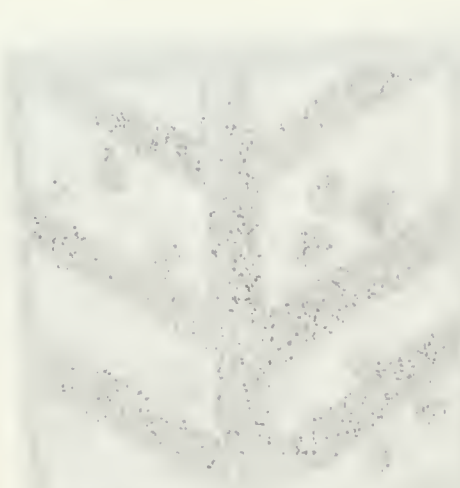
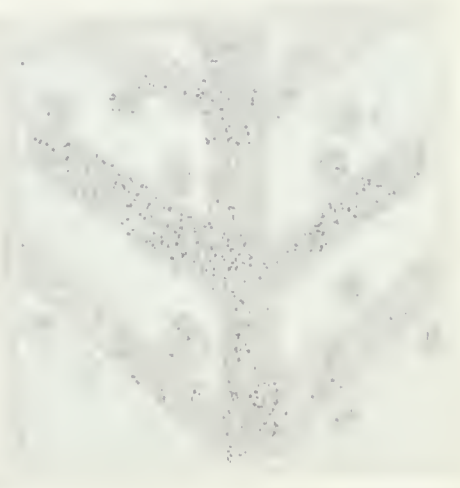
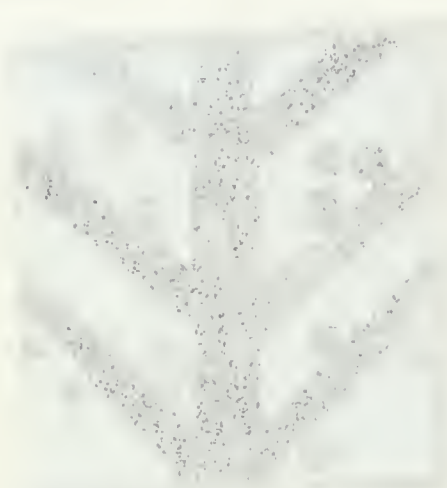
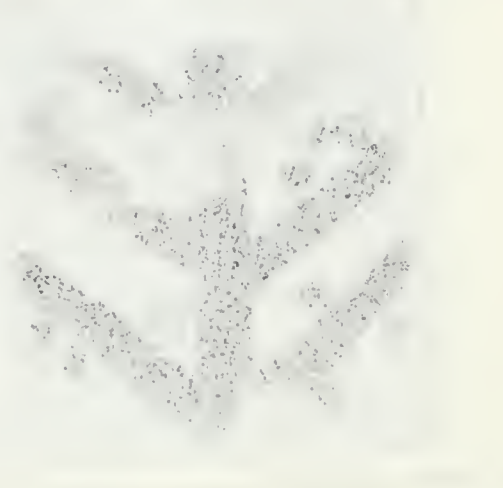
Fig. 103. Compatibility of Treatments: (Left) Sample D-18 after detachment with *strappo colletta* (Right) Untreated.



Fig. 104. Compatibility of Treatments: (Left) Sample D-19 after detachment with *stacco colletta* (Right) Untreated.



Fig. 105. Compatibility of Treatments: (Left) Sample D-21 after detachment with *strappo colletta* (Right) Untreated.



3.5 Final Testing Program

This chapter describes the final phase of research, treatment and detachment of the prototype samples on terra cotta substrates. It describes the detachment procedures and the final appearance of the paintings. The final conclusions are based on the results of these tests and are described in Chapter 4.

Summary:

Final conservation treatments were selected based on results of the preliminary testing program. Two techniques were used to evaluate methods and materials: visual assessment and observation of performance in standardized tests created by ASTM, the Federation of Societies for Coatings Technology, and CRATerre. Four specific types of conditions required treatment before detachment could be carried out:

- Powdering paint
- Interlayer detachment
- Lack of cohesion
- Lack of adhesion of the plaster and paint layers

Final tests were applied to nine prototype samples composed of seven painted ground/finish sequences on terra cotta tile substrates. One sample served as a control. Two samples had been treated, one with ethyl silicates, and one with ethyl silicate and poly (2-ethyl-2-oxazoline) (see page 117). Thus, the selected conservation materials were applied to six of the prototype samples, A, B, C, D, H, I. The two most successful of these treatments were then applied to the consolidated samples, G and J.

Objective:

Tests considered the following:

- Surface consolidation systems
- Preconsolidation systems
- Detachment systems for *strappo*
- Detachment systems for *stacco*
- Combined treatments

3.5.1 Methodology:**Treatment in Preparation for Detachment**

Samples A, B, C, D, H, I

The most effective preliminary treatment involved:

- Surface consolidation with eight spray applications of Acryloid B-72 (3% in toluene)
- Preconsolidation with water and pressure

Based on preliminary tests, Acryloid B-72 was selected as a surface consolidant to re-establish the cohesive strength of powdering paint. It effectively consolidated the paint without causing visible alteration or interfering with subsequent treatment. Only minor changes in porosity allowed penetration of subsequent treatment materials. Moreover, it made the paint layer to be insoluble in water, thereby permitting subsequent treatments with aqueous materials.

Therefore samples A, B, C, D, H, and I were prepared for detachment by consolidation of the surface with Acryloid B-72, and then preconsolidation using water brushed through Japanese tissue.¹³⁹ Pressure was applied through silicone release Mylar weighted with sandbags.

Samples G and J

Samples G had been preconsolidated earlier with a 50/50 mixture of Aquazol 50 (5% in ethanol) / T-1919. Both samples G and J were consolidated with the ethyl silicate monomer T-1919.

Application of facing adhesives: Samples A, B, C, D, H, I

Summary:

Based on the results of preliminary testing and their ability to meet the established criteria, *colletta* and polyvinyl alcohol facings were selected as facing adhesives to detach the mural paintings from Samples A, B, C, D, H, and I. These adhesives were viscous enough to prevent penetration of the plaster layers while remaining easily resolvable. Contraction of both the *stacco* and *strappo* forms of *colletta* alone was enough to detach large portions of plaster. Polyvinyl alcohol was selected for its easy resolubility and minimal residue after detachment. Two samples were faced with each adhesive and gauze

¹³⁹ Eight coats of Acryloid B-72 was the maximum that could be applied without causing unacceptable darkening or surface shine. Two aqueous solutions, Aquazol50® in a 5% solution in water and water alone were successful at reestablishing the adhesive and cohesive properties of the plasters, readhering delaminating layers, and facilitating manipulation of cleavage and deformation. Because it has not been tested in the field, Aquazol50® was not selected. For preconsolidation, water alone was used.

and hemp facings which provide support and protection to the painting during the detachment procedure.¹⁴⁰

The two most successful materials used on the first six prototypes were then applied to the ethyl silicate-consolidated samples, G and J. To permit the testing of two different facing adhesives, each of the ethyl silicate consolidated samples was divided in half.

***Colletta* (Samples A, D, H, I)**

Stacco colletta was heated in a double boiler and mixed with enough water to make a 50% solution. The *colletta* was then brushed on to the surface of the panels and faced with strips of 100% cotton gauze, overlapping by at least one centimeter, and leaving an excess of approximately ten centimeters around the perimeters of each painting.¹⁴¹ The excess fabric around the border of each painting was folded back upon itself to form a five-centimeter hem. The panels were then permitted to dry for approximately one to two days. While they were still soft a second coat of adhesive was applied. A secondary facing consisting of hemp fabric strips overlapping by approximately one centimeter, was laid on top of the warm glue. The *stacco* formula was applied to Samples A and D.

Strappo colletta was heated in a double boiler and mixed with enough water to make a 75% solution.¹⁴² Glue was brushed on to the surfaces of the paintings and each was

¹⁴⁰ Cotton gauze and hemp are the traditional materials used for the detachment of mural paintings in the *stacco* and *strappo* methods. For further discussion see Paolo and Laura Mora and Paul Phillipot, *The Conservation of Wall Paintings*, (Butterworths: London, 1984).

¹⁴¹ The cotton gauze must be washed to remove the size, and allowed to dry before application to the painting. Once applied to the surface of the painting, the gauze was stretched gently to avoid wrinkles or gaps on the surface.

¹⁴² The concentrations of both *colletta* glues were chosen empirically based on the most dilute solution capable of detachment without penetration of the plasters.

faced with strips of 100% cotton gauze in the above-described manner. As required for the *strappo* detachment process, a second layer of glue and hemp fabric facings were applied immediately afterwards. This facing was applied to Samples H and I.

Polyvinyl alcohol (Samples B, C)

Polyvinyl alcohol was dissolved in water at a concentration of 20% and applied to two panels, Samples B and C. Gauze facings were applied as above and the second layer of adhesive and hemp facings was applied immediately afterward.

Detachment (Samples A, B, C, D, H, I)

The following section describes the detachment procedure. A very sharp X-acto knife was used to make cuts around the perimeters of the paintings to be detached. Plywood panel supports, the same size as the sections to be detached, were placed against the surfaces of the faced paintings. The hems of the hemp canvases were turned up and over the rear of the panels and tacked into place. By this point, many of the paintings had partially detached due to the contraction of the *colletta* adhesive. If not wholly detached, one of two methods was used to free the paintings. In some instances, a padded mallet was tapped lightly over the surface of the support panel. In others, a 12-inch metal spatula was inserted between the layers of plaster partially freed and those still attached. The support panel, with the facings still tacked in place, was then pulled from the sample till the painting was completely freed.

Treatment after detachment:

Following detachment, plaster fragments still attached to the reverse of a painting were removed prior to reattachment to a new support to allow for a more stable bond between the painting and the support.¹⁴³ A 30% solution of polyvinyl acetate emulsion was applied to the back of each painting as an isolating layer to further facilitate a strong bond with the support. Preliminary tests on backing materials and adhesives supported the use of foam adhesive tape, to both cushion and adhere the fragile painted layers to plywood supports.¹⁴⁴

Strips of foam tape were adhered to the back of each painting until completely covered. Plywood supports coated with a 30% polyvinyl acetate emulsion were pressed onto the backs of the faced paintings.

Colletta facings were removed with a combination of water poultices and steam.¹⁴⁵

Polyvinyl alcohol facings were treated with water poultices for four to six hours prior to removing the facing. The procedure proved slightly more difficult than in preliminary testing.

¹⁴³ Fragments were cleared from the paintings using micro-spatulas and fine scalpels.

¹⁴⁴ Scotch Brand Foam Tape functioned as the temporary support for the final testing program.

¹⁴⁵ A portable clothing steamer was sufficient for panels of this size. *Colletta* facings should not be left on the surface of a painting beyond the point at which they first become firm. As they harden, the tenacity of the glue makes it very difficult to remove without significant amounts of water and steam, which can be detrimental to clay plasters. Excessive swelling may result in deformation and detachment. If detachment occurs, the lack of support behind the plaster layer can make facing and residue removal problematical.

Application of Facing Adhesives II: (Samples G₁, G₂, J₁, J₂)

Colletta and polyvinyl alcohol

The consolidated panels were divided into halves so that each could be tested with two different facing adhesives. Because the *stacco* form of *colletta* yielded the most favorable results based on visual assessment of samples A, D, H, and I after detachment, it was applied to one half of each of the consolidated samples. A 20% solution of polyvinyl alcohol in water was applied to the other half. Primary and secondary facings were applied using the previously described methodology. Polyvinyl alcohol facings were removed using water poultices. *Colletta* facings were removed using a combination of water poultices and steam.

Results of prototype detachments are described in Tables 32 and 33. Table 34 quantifies the results of each detachment by listing the percentages of discrete plaster layers remaining on the substrate after detachment. The * symbol in the following tables stands for the spray-applied preconsolidant made from a 50/50 (v/v) solution of Aquazol 50® (5% in ethanol) / T-1919.

Observations:

Four of the six samples faced with the *colletta* adhesive detached naturally as a result of the contraction of the glue. The best result, based on visual assessment of the reattached paintings, was attained with the *stacco* formula, which exhibited only minimal losses and cracking. Despite the more impressive performance of polyvinyl alcohol

facings during preliminary testing, paintings detached using *stacco colletta* showed the least deterioration during final testing.

Samples treated with both the Aquazol 50®/T-1919 preconsolidant and the T-1919 consolidant were detached with both the *stacco colletta* and polyvinyl alcohol facings. The *stacco* sample exhibited significant losses. The sample faced with polyvinyl alcohol exhibited only slight powdery losses but residue removal caused abrasion of the paint layer.

Samples consolidated with T-1919 were also detached using *stacco colletta* and polyvinyl alcohol facings. The painting detached using the *stacco* adhesive exhibited negligible losses at its edges.¹⁴⁶ The polyvinyl alcohol facing resulted in the most *strappo*-like detachment. Approximately 95% of the painting detached between the top two layers.

Each method was successful at removing the surface paint layer and at least one layer of plaster as a whole. However it was not possible to limit detachment to a specific consistent layer. Consequently, indiscriminate detachments resulted in extensive

¹⁴⁶ Losses of paint and plaster probably occurred due to a lack of support behind the paint layer. After each painting was detached, fragments of underlying plaster layers were cleared from the back surface until a consistent layer was reached. Plaster was not removed down to the paint layer. Paintings were reattached to a new support and facings were removed using water poultices and steam. The introduction of water caused the clay plasters to swell and deform. The bottom layer often remained adhered to the new support while the surface layer swelled and partially delaminated. Sections of the paint layer were then left unsupported, increasing the losses of both paint and plaster during facing and residue removal. Reports on previous treatment indicate that a lack of support directly behind the paint layer was the cause significant losses of material during the 1960s program. (See Appendix A) Initially, the removal of supporting plaster layers from the backs of paintings did not reach down to the paint layer. Consolidation of the painted surface and the rear surface resulted in a zone of unconsolidated plaster between them. Differential rates of contraction and expansion between the three zones caused the unconsolidated layer to crumble, leaving the paint layer unsupported and extremely fragile.

fragmentation of plaster layers remaining on the substrate. Slight but not unacceptable darkening occurred on the surface of all the samples. Analysis of post-detachment layer distribution (see Table 34) revealed no consistent pattern of fragmentation. Detailed detachment results are located in Tables 32 and 33.

3.6 Evaluation of Final Testing Program

This section reports on the effectiveness of treatment measured by various tests standardized by the American Society for Testing and Materials and the Federation of Societies for Coatings Technology. Tests were designed to evaluate the performance of coatings, specifically paint films, on the basis of three conditions: cracking, flaking, and checking. These tests allowed the researcher to compare the effects of various treatments on the painted plaster surfaces using standardized rating scales and photographic references. Samples were classified by color notation using the Munsell System before and after treatment. Comparison to standardized color chips facilitated the evaluation of treatment-related color changes.

Summary:

Detachments were evaluated by standardized visual assessment tests. ASTM standard tests used to assess visual appearance of the samples included: D 661-86: "Standard Test Method for Evaluating Degree of Cracking of Exterior Paints," D 772-86: "Standard Test Method for Evaluating Degree of Flaking (Scaling) of Exterior Paints," and D 1535-80: "Standard Method of Specifying Color by the Munsell System," and D 660:

“Standard Test Method for Evaluating the Degree of Checking of Exterior Paints.” Each of these tests provides a standard of comparison by which to compare the appearance of the detached samples to the untreated samples. All of these tests, excluding color specification are based on pictorial photographic reference standards contained in the *Pictorial Standards of Coatings Defects* distributed by the Federation of Societies for Coatings Technology in Blue Bell, Pennsylvania.¹⁴⁷

¹⁴⁷ Federation of Societies for Coatings Technology, *Pictorial Standards of Coatings Defects*, (Pennsylvania: Federation of Societies for Coatings Technology).

3.6.1 ASTM D661-86: Evaluating Degree of Cracking of Exterior Paints

Summary:

ASTM defines three types of cracking: irregular pattern type, in which no definite pattern is evident; line type, in which the cracks generally occur in parallel lines often following brush marks; and sigmoid type, in which the cracks form a pattern of intersecting curves.¹⁴⁸ The *Pictorial Standards of Coating Defects* consists of silver halide photographs that provide standards of comparison for each test.¹⁴⁹ Each photograph has a numerical rating descriptive of the degree of cracking it represents.

Objective:

The purpose of this test was to visually assess and compare the degree of cracking of treated and untreated samples using pictorial reference standards.

Methodology:

Each sample was compared to the pictorial standards and given a numerical rating. Comparisons were drawn between the effects of the different treatments and between treated and untreated samples. Results are listed in Tables 35 and 36. In all of the following tests, a rating of 2 represents the worst case scenario.

¹⁴⁸ ASTM "ASTM D661-86: Evaluating Degree of Cracking of Exterior Paints," in *1990 Annual Book of ASTM Standards Section 6: Paints, Related Coatings and Aromatics* (Philadelphia: ASTM, 1990), 82-83.

¹⁴⁹ The photographs illustrate line type cracking only but are intended as a reference for all types.

3.6.2 ASTM D772-86: Evaluating Degree of Flaking (Scaling) of Exterior Paints

Summary:

The term flaking refers to the detachment of pieces of a paint layer from its substrate.¹⁵⁰ The degree of flaking of the painted surface following detachment may be evaluated by comparison with photographic reference standards.

Objective:

The purpose of this test was to visually evaluate and compare the degree of flaking on the surface of the treated and untreated samples to pictorial reference standards and to each other.

Methodology:

Treated and untreated samples were compared to the pictorial standards and given a numerical rating. The effects of different treatments, and of treated and untreated samples were compared. Ratings are listed in Tables 35 and 36.

¹⁵⁰ ASTM, "ASTM D772-86: Evaluating Degree of Flaking (Scaling) of Exterior Paints," in *1990 Annual Book of ASTM Standards Section 6: Paints, Related Coatings and Aromatics* (Philadelphia: ASTM, 1990), 97-100.

3.6.3 ASTM D660 Evaluating Degree of Checking of Exterior Paints

Summary:

ASTM defines checking as breaks in a film that do not penetrate to earlier layers or to the substrate.¹⁵¹ “Line checking” is identified by checks on a surface arranged in horizontal or vertical parallel lines that often follow brushstrokes. “Crowsfoot checking” describes breaks in a film that form a three way like a crowsfoot. Checks run from the center and form an angle of approximately 120° between the two ends. “Irregular checking” does not exhibit a definite pattern but often exhibits a combination of the first two. The pictorial standards are assigned to a numerical rating system ranging from 2-10. A rating of 10 refers to films that exhibit no checking.

Objective:

The purpose of this test was to visually evaluate and compare the occurrence of checking on the surface of both treated and untreated samples to pictorial reference standards.

Methodology:

Samples were observed and assigned the number best representing the degree of checking present. Comparisons were then made between the treated and untreated samples. Ratings are listed in Tables 35 and 36.

¹⁵¹ ASTM, “ASTM D660 Evaluating Degree of Checking of Exterior Paints,” in *1990 Annual Book of ASTM Standards Section 6: Paints, Related Coatings and Aromatics*, (Philadelphia: ASTM, 1990), 72-81.

Observations:

Both the *strappo* and the polyvinyl alcohol samples exhibited a significant degree of flaking, except those that had first been consolidated. The *stacco* sample preconsolidated with Aquazol 50/T-1919 exhibited a significant degree of flaking.

One *strappo* and both consolidated *stacco* samples exhibited significant cracking, probably due to the swelling and interlayer detachment caused by the water-based residue removal method. The remainder of the samples exhibited only slight cracking after detachment.

One *stacco* sample exhibited minimal checking after detachment. Neither type, nor occurrence of deterioration was specific to any one treatment.

3.6.4 ASTM D 1535-80 Specifying Color by the Munsell System

Summary:

The Munsell System of Color Specification assigns color notations based on the properties of hue, value and chroma, as visually perceived by an observer under normal daylight conditions.¹⁵² The notations follow the formula: HV/C. A letter expresses hue, the property that classifies a color by name, such as red. Value, a measure of daylight reflectance, is expressed on a scale of 0 to 10; 0, representing true black, and 10, true white. Chroma refers to the degree of saturation of the colored surface, and is expressed on a scale of 0 to 20. Painted samples may be visually assessed next to standard color chips provided with the kit. This system provides a method of visually assessing the effects of treatment on the optical properties of the plasters.

Objective:

The purpose of this test was to evaluate the effects of treatment on the optical properties of the samples by assigning specific color notations to the painted plaster before and after treatment.

Methodology:

Prototype panels were observed in the conservation laboratory before and after treatment under natural daylight illumination from a north window. Painted samples were compared to chips from the matte edition of the Munsell Book of Color. The colors

¹⁵² ASTM, "ASTM D 1535-80 Specifying Color by the Munsell System," in *1990 Annual Book of ASTM Standards Section 6: Paints, Related Coatings and Aromatics*, (Philadelphia: ASTM, 1990), 182-208.

rated were red, black and the unpainted white plaster. Several color notations were noted for each color on each sample to account for the mottled surfaces of the prototypes. In order to better assess the effects of treatment, color notations before and after treatment are listed together in Table 37. Table 38 interprets the data on the effects of treatment on painted and unpainted samples.

Observations:

Most samples exhibited a slight yellowing of the surface. The unconsolidated samples faced with polyvinyl alcohol were the only two to resist yellowing of the unpainted plaster surface. No other alteration in hue was observed. All the samples exhibited a slight discontinuous darkening of the surface, due at least in part, to adhesive residue. In some areas, the paintings were lighter, probably due to abrasion from facing and residue removal.



Fig. 106. Prototype A: Untreated



Fig. 107. Sample A: After detachment



Fig. 108. Prototype B: Untreated



Fig. 109. Sample B: After detachment



Fig. 110. Prototype C: Untreated



Fig. 111. Sample C: After detachment



Fig. 112. Prototype D: Untreated



Fig. 113. Prototype D: after detachment



Fig. 114. Prototype G: Untreated

Fig. 115. Prototype G_1 : after detachmentFig. 116. Prototype G_2 : after detachment

Fig. 117. Prototype H: Untreated



Fig. 118. Prototype H: after detachment



Fig. 119. Prototype sample 1: Untreated



Fig. 120. Prototype sample 1: After detachment



Fig. 121. Prototype sample J: Untreated



Fig. 122. Prototype sample J_1 :
After detachment

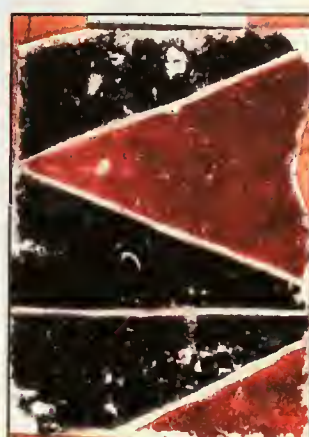


Fig. 123. Prototype sample J_2 :
After detachment



Fig. 124. Substrate Sample A: after detachment

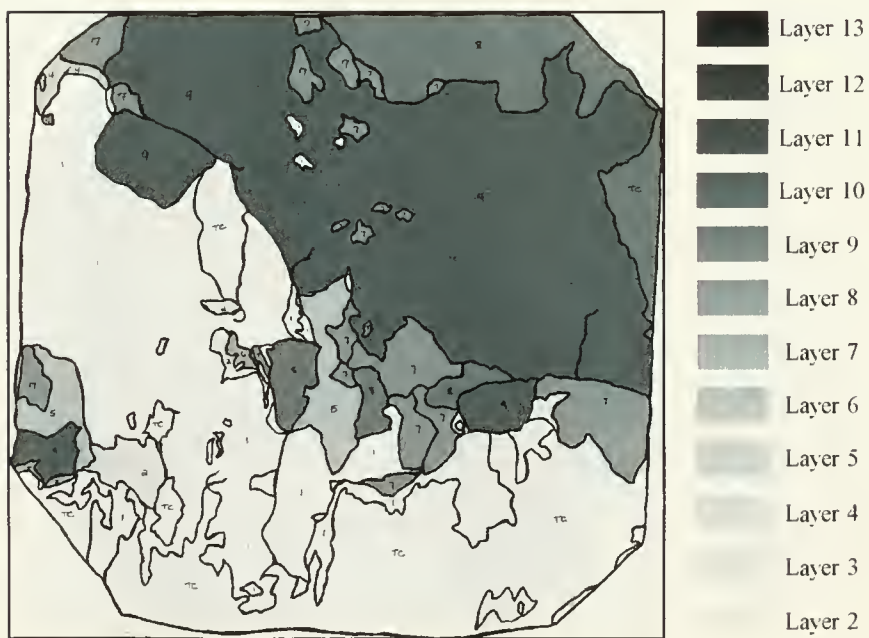


Fig. 125. Sample A: Layers remaining on substrate after detachment



Fig. 126. Substrate Sample B: after detachment

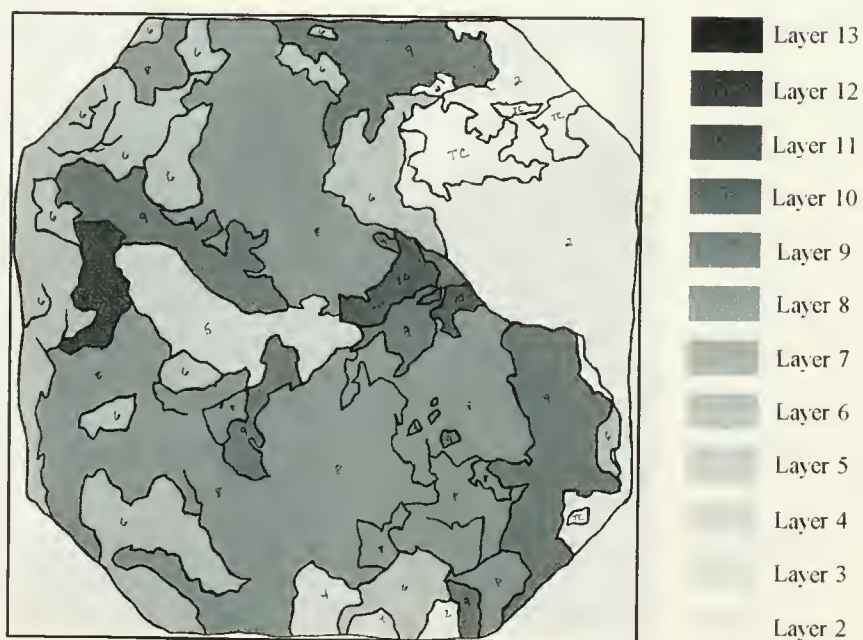


Fig. 127. Sample B: Layers remaining on substrate after detachment





Fig. 128. Substrate Sample C: after detachment



Fig. 129. Sample C: Layers remaining on substrate after detachment



Fig. 130. Substrate Sample D: after detachment

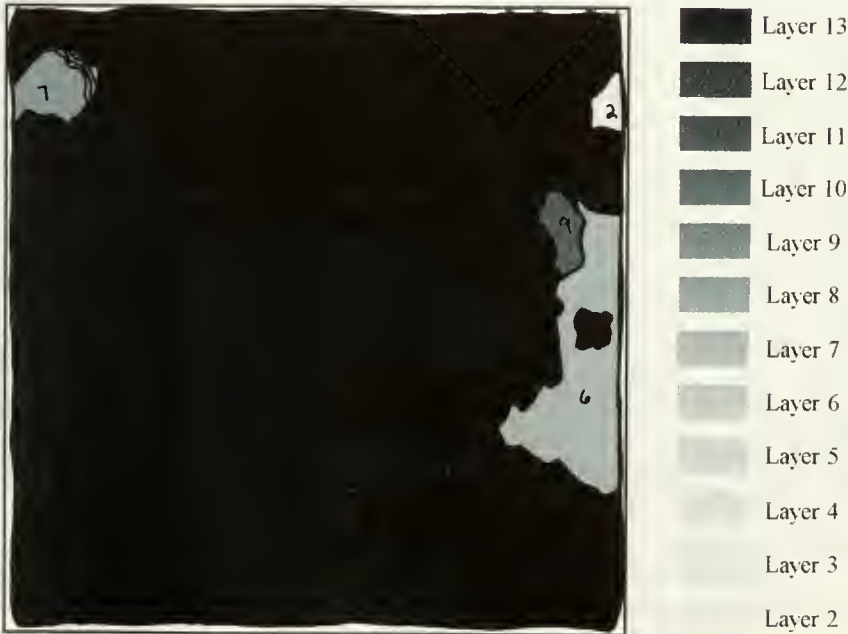


Fig. 131. Sample D. Layers remaining on substrate after detachment

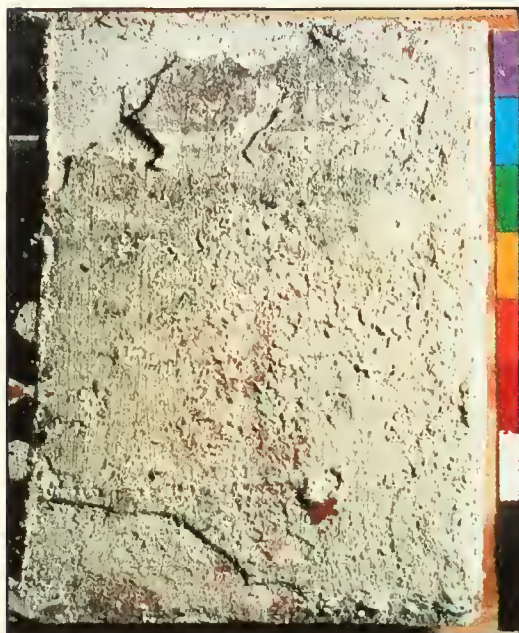


Fig. 132. Substrate Sample G_1 :
after detachment



Fig. 134. Substrate Sample G_2 :
after detachment



Fig. 133. Sample G_1 :
Layers remaining on substrate after
detachment

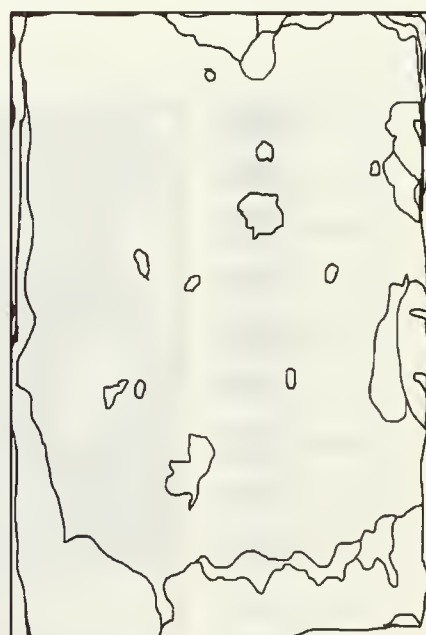
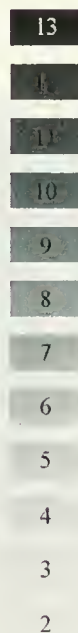


Fig. 135. Sample G_2 :
Layers remaining on substrate after
detachment





Fig. 136. Substrate Sample H: after detachment

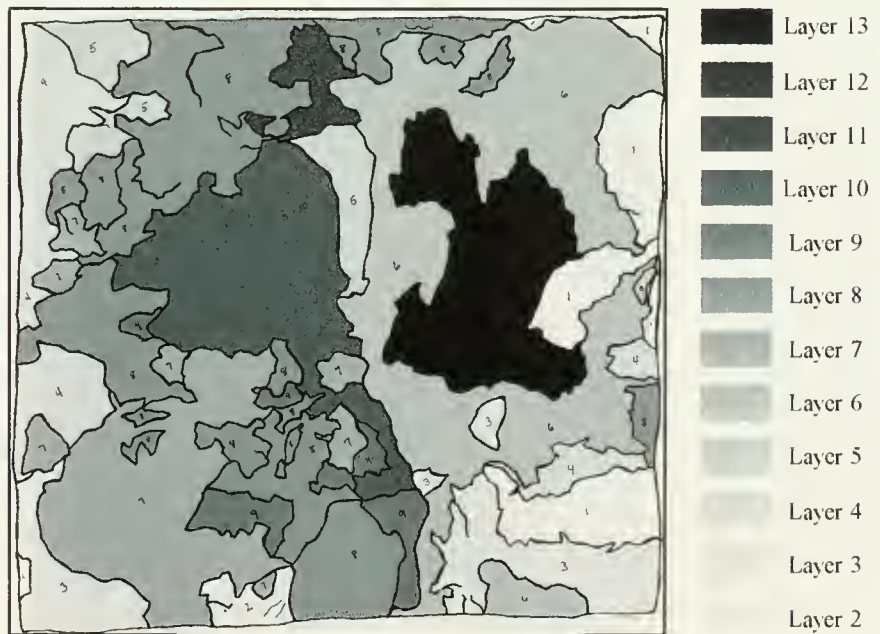


Fig. 137. Sample H: Layers remaining on substrate after detachment





Fig. 138. Substrate Sample 1, after detachment



Fig. 139. Sample 1: Layers remaining on substrate after detachment

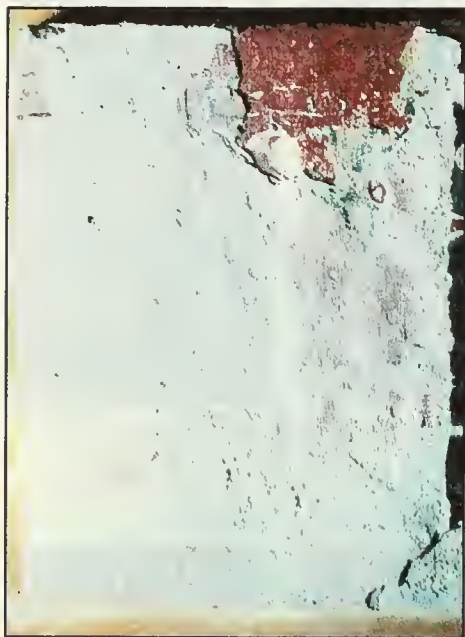


Fig. 140. Substrate Sample J_1 :
after detachment



Fig. 142. Substrate Sample J_2 :
after detachment



Fig. 141. Sample J_1 :
Layers remaining on substrate after detachment



Fig. 143. Sample J_2 :
Layers remaining on substrate after detachment

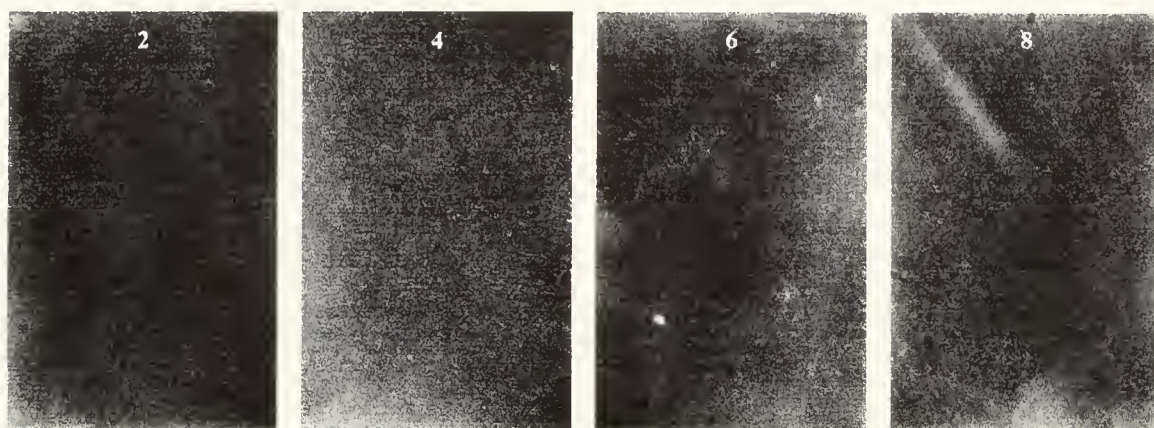


Fig. 144. Rating Scale for ASTM D660 : Evaluating Degree of Checking of Exterior Paints

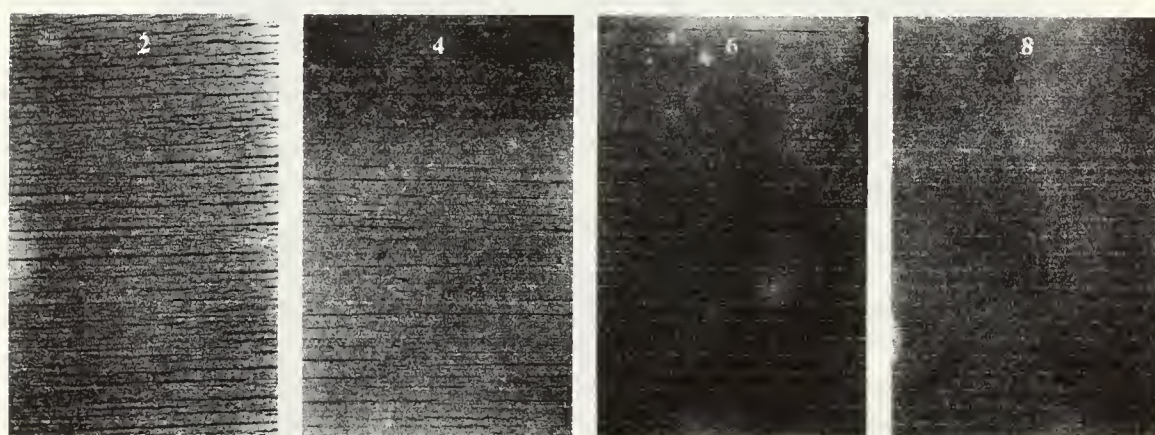


Fig. 145. Rating Scale for ASTM D661-86 : Evaluating Degree of Cracking of Exterior Paints

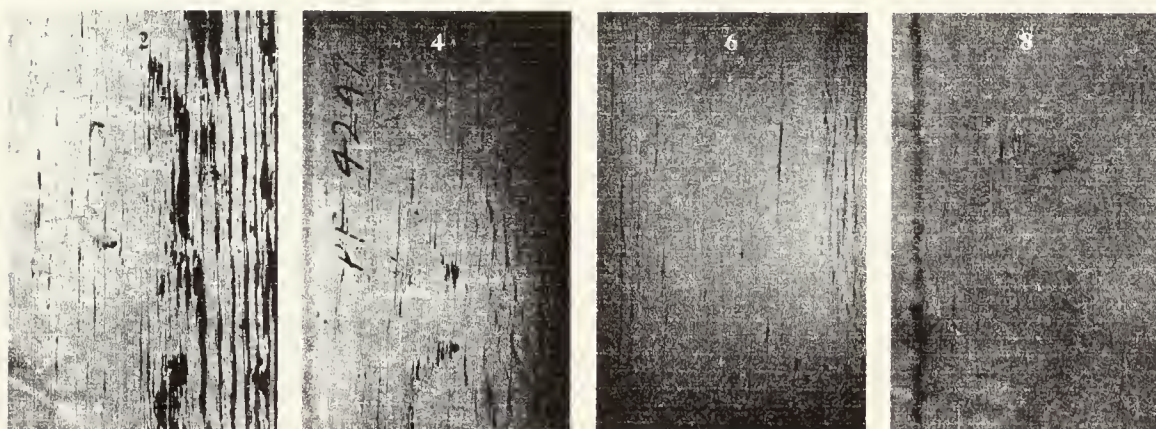


Fig. 146. Rating Scale for ASTM D772-86 : Evaluating Degree of Flaking (Sealing) of Exterior Paints



Fig. 145. Overview of test samples

Chapter 4: Conclusions

4.1 Final results

This research program addressed two principal requirements for the preservation of the wall paintings on earthen plaster supports at Çatalhöyük: emergency stabilization and removal. Results of a series of eighteen tests indicated that two systems of treatment were successful at strengthening the paint and plaster surfaces and facilitating detachment of the mural paintings.

This section summarizes the results of the testing program. Test-specific data is organized into tables beginning on page 189. Each summary of treatment provides a reference to the corresponding tables. The chapter closes with conclusions and recommendations for further research.

Summary

Methods for preliminary treatment and emergency stabilization were required to handle the following conditions:

- Powdering paint and plaster
- Interlayer detachment
- Disaggregation of the earthen plaster

In response to these conditions, the following tests were conducted:

- Consolidation treatments
- Facing adhesives for mural detachment
- Detachment methods
- Compatibility of treatments

Tests were conducted on laboratory facsimiles due to the limited number and size of painted plaster samples available from the site. Samples were composed of multiple plaster and paint layers similar in character to those found in Turkey. Fragile conditions, similar to that found on site, were created by applying a weak pictorial layer to an expansive clay plaster support.

The loss of cohesive strength within discrete layers and adhesive strength between individual layers of the Çatalhöyük plasters and mural paintings required two different types of pretreatment. A preconsolidant was needed to impart cohesive strength to the surface while enabling the application of additional treatment and preserving the optical properties of the painted plaster. Another type of adhesive was required to readhere separated layers, reattach flaking paint and plaster layers, and relax cleavage of the surface.

The following section summarizes the most successful methods and materials for each phase of treatment. It is followed by the supporting data, organized into tables for clarity. Shaded cells indicate a positive result.

4.1.1 Surface Consolidation

Results of preliminary testing indicated that multiple spray applications of an acrylic resin, Acryloid B-72, in a 3% solution in toluene were the most successful surface consolidant, making the pigment layer insoluble in water and strengthening the surface of the painted layer and plaster without altering their optical properties. B-72 was able to quickly bond loose particles to the support and prevent losses in the paint layer without

interfering with the effectiveness of the preconsolidation treatment. Using multiple applications of a dilute solution permits sufficient penetration within the plaster to prevent the formation of a surface film. For more detailed information, please refer to Tables: 6-9, 12-14, 19-21.

4.1.2 Readhesion

Several tests were used to evaluate materials for the reestablishment of adhesion between detached layers. Applications of both water and Aquazol 50, a non-ionic polymer adhesive, in a 5% solution in water, improved adhesion between plaster layers previously exhibiting cleavage and separation. The effects of water on the behavior of clay and clay plasters has been explained in section . By using water or another aqueous material as a preconsolidant, it was hoped that this water-sensitivity could be used to facilitate manipulation of deformed plaster layers. Aqueous materials cause the clay plasters to swell and soften. When combined with the application of pressure, delaminated, deformed and cracked plaster layers show an improvement in readhesion, relaxation and compaction. For more detailed information, please refer to Tables: 8-14, 20, 21, 28-31.

4.1.3 Consolidation

Consolidation of disaggregating earthen plaster and mudbrick using ethyl silicates proved to strengthen the plaster layers and the surface. Consolidated samples exhibited a visually appreciable strengthening of the surface, as witnessed by their performance in standardized tests in comparison to untreated samples. In all but the CRATerre Water

Drop Test, the samples consolidated only with T-1919 performed more successfully than the samples preconsolidated with the Aquazol50/T-1919 mixture, then consolidated with T-1919. For more detailed information, please refer to

Tables: 12, 13, 14, 19-27, 32,33

4.1.4 Facing adhesives for mural detachment

Six types of adhesives were tested as facing materials for mural detachment. Two of these were effective, *colletta*, a collagen-based adhesive traditionally used for the techniques of *strappo* and *stacco*, and polyvinyl alcohol, a water-soluble synthetic adhesive. Both provided adequate adhesion over the entire painted surface to permit detachment at a consistent level without penetrating the surface of the plaster. They were not adversely affected by materials used for pretreatment. Both facilitated detachment. Contraction of the *colletta*, particularly, causes lifting of the paint layer without mechanical intervention. Both provided support to the detached plaster layer. Polyvinyl alcohol facings were easily removed using multiple applications of water poultices. *Colletta* facings were most easily removed using a combination of water poultices and steam. Preliminary tests indicate that either may be used with minimal alteration of the painted surface. For more detailed information, please refer to

Tables: 10, 11, 15, 16, 28-38.

4.1.5 Detachment methods

Two levels of detachment developed for the detachment of paintings on lime plaster were considered for this research, *strappo*, removal of the paint layer alone; and

stacco, removal of the paint layer along with its plaster rendering. The removal of walls *in toto* was considered in another phase of research. None of the facing adhesives or techniques provided the control necessary to attain a consistent level of detachment throughout a sample. Although the recipe and technique for the *stacco* and *strappo* forms of detachment have been designed to accommodate the lifting of either the paint layer alone or the paint with its rendering, it was not possible to remove discrete layers. For more detailed information, please refer to

Tables: 28-38.

4.1.6 Reattachment to a new support

Although this aspect of work was not the focus of the research, a simple method for attaching detached murals to a new backing was required in order to proceed with testing. In order to continue research, the use of temporary materials was required to support the paintings. Scotch Brand Foam Tape provided the contact adhesive and degree of cushion required to support the fragile paintings. It must be emphasized that this material is in no way meant to act as a conservation alternative. Use of this material was required only by the need to proceed with testing to obtain results regarding treatment compatibility and facing adhesives. For more detailed information, please refer to Tables: 17,18.

4.1.7 Compatibility of treatments

A combination of conservation treatments was required. Once individual materials were selected for the treatment of powdering paint, interlayer detachment, and

cleavage of the surface layer, it was necessary to address their compatibility with one another and with methods of mural detachment. Compatibility was assessed using the following criteria:

- Preservation of original appearance: color, gloss, texture, surface form
- Success at achieving the objective: efficient detachment of the plaster stratum as a whole or of a discreet layer
- Successful reattachment of the painting to a new support
- Removal of the facing adhesive with little or no damage to the painted plaster surface

For more detailed information, please refer to Tables: 28-31.

4.1.8 Final testing program

Results of the preliminary testing program were evaluated to inform the final testing program. The most effective treatments were used for the pretreatment and detachment of ten prototype facsimiles. Six samples composed of fourteen layers of plaster and seven replicated mural paintings were treated with eight spray applications of Acryloid-B72, 3% in toluene. Water was used in combination with pressure to preconsolidate the plasters. Paintings were detached using the polyvinyl alcohol and both the *stacco* and *strappo colletta* facings.

The most successful detachments, carried out with the polyvinyl alcohol and *stacco colletta* facings were then used to detach the samples consolidated with ethyl silicates. Results based on visual assessment of the reattached paintings ranged from fair

to very good. Most of the detached murals exhibited a slightly darkened surface and uneven gloss due to residue from the facing adhesives. Most of the paintings exhibited minimal losses of the plaster and paint, probably due to a lack of support behind the paint layer. This lack of support, caused by swelling and delamination of the plaster layers during facing removal, made it nearly impossible to completely remove adhesive residue. Contraction of the residue may have been the cause of localized areas of delamination of the painted surface. For more detailed information, please refer to Tables: 32-38.

4.1.9 Detachment of consolidated samples

The condition of samples consolidated with ethyl silicates did not differ significantly from other samples after detachment. Consolidated samples detached using the polyvinyl alcohol facing exhibited less cracking than other samples. Results were otherwise unremarkable. For more detailed information, please refer to Tables: 32-38.

4.2 Final Results: Data

The following section contains data from all tests conducted during the laboratory research program.

Table 6

Visible Alteration of the Plaster Surface			
H₂O - Quickly absorbed - Slight softening/swelling	Rabbit skin glue (5% in H₂O) Glossy film formation	Ethanol No visible change	Isopropanol No visible change
Acetone No visible change	B-72 (7% in xylene) Slight discoloration	B-72 (10% in xylene) Slight discoloration	
T-1919® No visible change	Aquazol 50® (5% in ethanol) Glossy film formation	Aquazol 50® (10% in ethanol) - Glossy film formation - Slight discoloration - Negligible cracking	Aquazol 50® (5% in ethanol) No visible change
Aquazol 50® (10% in isopropanol) Slight discoloration	Aquazol 50® (5% in H₂O) No visible change	Aquazol 50® (10% in H₂O) - Slight discoloration - Cracking	Aquazol 50® (5% in ethanol) / T-1919® 50/50 (v/v) No visible change

Effects of solvents, adhesives, and consolidants on the optical properties of the plaster surface of a 6-by-6-inch unpainted multiple-layer sample on gypsum board.

Table 7

Surface Consolidation			
<u>Gum arabic (10% in H₂O)</u> 1 application • *Darkens, becomes transparent when wet • Less friable • Little or no visible alteration	<u>Gum arabic (5% in H₂O)</u> 1 application • * • Less friable • Slight sheen	<u>Rhoplex AC-33 (5% in H₂O)</u> 1 application • * • Less friable • Filmy residue	<u>Rhoplex AC-33(10% in H₂O)</u> 1 application • * • Less friable • Slight filmy residue
	<u>B72 (5-15% in toluene)</u> 1 application • * • Negligible darkening • Less friable	<u>B72 (5-15% in toluene)</u> 2 applications • * • Slight darkening • Less friable	<u>B72 (5-15% in toluene)</u> 3 applications • * • Darkened • Less friable
<u>Aquazol 50® (5% in isopropanol)</u> 1 application • * • Yellowish darkening	<u>Aquazol 50® (10% in isopropanol)</u> 1 application • * • Yellowish darkening • Less friable	<u>Gelatin (5% in H₂O)</u> 1 application • * • Somewhat friable • Little or no visible alteration	<u>Gelatin (5% in H₂O)</u> 2 applications • * • Sheen • Not friable
	<u>Aquazol 50® (5% in H₂O)</u> 1 application • * • Slight darkening • Less friable	<u>Aquazol 50® (5% in ethanol)</u> 1 application • * • Less friable • Little or no visible alteration	<u>Aquazol 50® (5% in ethanol)</u> 2 applications • * • Less friable • Little or no visible alteration

Test designed to identify a material to strengthen the surface of the plaster while preserving its optical properties carried out on 12-by-12 inch unpainted multi-layer sample on concrete block.

Table 8

Surface Consolidation and Preconsolidation with Readhesion I		
<u>Aquazol 50® (5% in ethanol)</u> 1 application • No swelling • Remained brittle • Delaminates from substrate • Slightly darkened	<u>Rhoplex AC-33 (1% in H₂O)</u> 1 application • Swelling due to H₂O • Malleable when rolling • Can be pressed into plane • Slightly darkened • Weighted • Cleavage partially relaxed	<u>Gum arabic (10% in H₂O)</u> 1 application • Slow absorption rate • Swelling • Can be pressed into plane • Weighted • Delaminates from substrate
<u>Aquazol 50® (5% in H₂O)</u> 2 applications • Swelling • Can be pressed into plane • Weighted	<u>H₂O</u> 1 application • Swelling • Can be pressed into plane • Remained flattened after drying • More compact • Better adhered to substrate	<u>Aquazol 50® (10% in isopropanol)</u> 2 applications • No swelling • No flattening • Strengthened • Well adhered to substrate
<u>Gelatin (5% in H₂O)</u> 1 application • Swelling • Partially relaxes cleavage • Slightly darkened • Weighted • Still cleaving but apparently strengthened • Well adhered to substrate	<u>Gum arabic (5% in H₂O)</u> 1 application • Swelling • Partially relaxes cleavage • Not quite dry • Slightly flattened • Weighted • Separates from substrate	<u>H₂O</u> 1 application • Swelled • Began to dissolve • Can be pressed into plane • Weighted • Began to cleave after drying

This test, carried out on a 6-by-6-inch unpainted sample of sodium bentonite and water on gypsum board, aimed to identify materials capable of improving the cohesive and adhesive strength of the plaster surface without altering its optical properties and to improve interlayer attachment and relax cleavage.

Table 9

Surface Consolidation and Preconsolidation with Readhesion II	
<u>Gelatin (5% in H₂O)</u> 1 application • Slight darkening • Less friable	<u>Rhoplex AC-33 (1% in H₂O)</u> 1 application • Uneven, slight darkening • Uneven sheen • Rolled
<u>Rhoplex AC-33 (0.5% in H₂O)</u> 1 application • Darkened • Slight, filmy sheen • Less friable	<u>Rhoplex AC-33 (0.5% in H₂O)</u> 1 application • Uneven, slight sheen • Less friable • Rolled
<u>B-72 (5-15% in toluene)</u> 1 application • Darkened • Still slightly friable	<u>Gelatin (5% in H₂O)</u> 1 application • No darkening • Still friable
<u>Aquazol 50® (5% in ethanol)</u> 1 application • Slight darkening • Slightly less friable	<u>Aquazol 50® (5% in H₂O)</u> 2 applications • Slightly less friable after 1 coat • Rolled • Weighted • More compacted
<u>Aquazol 50® (5% in H₂O)</u> 1 application • Slight darkening • Still friable	<u>H₂O</u> 1 application • Friable • More compacted

This test, carried out on one 12-by-12-inch painted multi-layer concrete block, aimed to strengthen the plaster surface while preserving the original appearance and improve interlayer attachment between plaster layers exhibiting cleavage and separation.

Table 10

Readhesion / Facing Adhesives	
D1 <u>B-72 (8% in xylene): brushed through tissue</u> - Stabilizes paint layer - Slightly impedes H₂O absorption - Causes brownish discoloration - Divided in half (D1A and D1B) for additional treatment	
D1A <u>H₂O: spray applied</u> - Permits manipulation without smearing <u>Aquazol 50®(5% in H₂O): spray applied</u> - Improves delamination - Improves adhesion between pieces - Relaxes cleavage - Slightly strengthens	D1B <u>H₂O: spray applied</u> - Improves delamination in isolated areas - Permits manipulation without smearing - Improves adhesion between pieces
D2 <u>H₂O: spray applied</u> - Improves adhesion to the substrate and between pieces - Swells the cleaved plaster surface which is then flattened by applying pressure over mylar	
D2A <u>Aquazol 50®(5% in H₂O): spray applied</u> - Swells the plaster surface which is then flattened by applying pressure over mylar - Improves craquelure, cleavage - Allows compaction and readhesion between cracked pieces - Dissolves paint layer without preliminary B-72 application	D2B <u>B-72 (8% in xylene): brushed through tissue</u> <u>Aquazol 50®(5% in H₂O): spray applied</u> - Slightly darkens - Swells the plaster surface which is then flattened by applying pressure over mylar - Improves craquelure, cleavage - Allows compaction and readhesion between cracked pieces - Preserves paint layer
D3 <u>Plextol B500(50% solids): brushed through tissue</u> - Fully adheres plaster to tissue - Permits full-scale delamination of plaster	

Results of tests designed to evaluate the performance of materials as adhesives for separated plaster layers and as facing adhesives for mural detachment.

Table 11

Readhesion / Facing Adhesives	
D4	<u>B-72 (8% in xylene): brushed through tissue</u> <u>H₂O: spray applied</u> • Readheres plaster to substrate • H₂O application improves craquelure, cleavage • Allows compaction and readhesion between cracked pieces • B-72 application inhibits loss of paint layer • Causes slight discoloration
D5	<u>Microcrystalline Wax/Mineral Spirits</u> • Incomplete penetration • Significantly discolours plaster and paint layer
D6	<u>B-72 (3% in xylene)- brushed through tissue</u> <u>Aquazol 50®(5% in H₂O): spray applied</u> • Causes adhesion of the plaster layer to the mylar • Causes complete delamination of the surface from the substrate • Permits manipulation to relax cleavage and readhere cracked pieces
D7	<u>B-72 (3% in xylene)- brushed through tissue</u> <u>Aquazol 50®(5% in H₂O): spray applied</u> • Permits manipulation to relax cleavage and readhere cracked pieces • Preserves the paint layer • Causes slight discoloration • Provides limited readhesion to the substrate
D8	<u>Microcrystalline wax / Mineral spirits</u> • Exhibits incomplete penetration • Significantly discolours plaster as well as the paint layer
D9	<u>Microcrystalline wax / Mineral spirits</u> • Exhibits incomplete penetration • Significantly discolours plaster as well as the paint layer

Results of tests designed to evaluate the performance of materials as adhesives for separated plaster layers and as facing adhesives for mural detachment.

Table 12

Surface Consolidation of Powdering Paint with Consolidation and Readhesion	
C-4: 2 ground/finish phases, 2 paintings on 12" gypsum board panel	
C-4a <i>B-72 (8% in xylene, spray applied): 3 coats</i> <i>H₂O (spray applied)</i> <i>Weighted</i> • Without application of weight, H₂O causes delamination from substrate • Permits manipulation of deformation • Slightly darkens • Relaxes cleavage • Permits readhesion to substrate	C-4b <i>B-72 (8% in xylene, spray applied): 2 coats</i> <i>H₂O (spray applied)</i> • B-72 fixes paint surface • Permits manual manipulation of deformation • Does not provide strength • H₂O causes delamination from substrate Then: • <i>Aquazol 50 (5% in H₂O, spray applied)</i> • Slightly darkens • Relaxes cleavage slightly less than C-4a
C-4c <i>B-72 (3% in xylene, spray applied): 2 coats</i> <i>Aquazol 50 (5% in H₂O, brush applied)</i> • H₂O causes plaster to swell • Permits manipulation of deformation • Relaxes cleavage • Strengthens bond between plaster pieces • Does not strengthen bond between large detached pieces and substrate	C-4d <i>B-72 (3% in xylene, spray applied): 2 coats</i> <i>Aquazol 50 (5% in isopropanol, brush applied)</i> • H₂O causes plaster to swell • Permits manipulation of deformation • Relaxes cleavage • Strengthens bond between plaster pieces • Causes yellow discoloration

Result of test carried out on three 12-by-12-inch painted multi-layer gypsum board panels designed to treat the loss of adhesion and cohesion of the paint layers without altering the optical properties of the plaster or painting.

Table 13

Surface Consolidation of Powdering Paint with Consolidation and Readhesion	
C-5: 2 ground/finish phases, 2 paintings on 12" gypsum board panel	
C-5a <i>B-72 (3% in xylene, spray applied): 2 coats</i> <i>H₂O (spray applied): 2-3 coats</i> • B-72 consolidates paint surface • H₂O causes swelling and delamination of plaster from substrate • Permits manipulation of deformation • Relaxes cleavage • Does not strengthen bond between large detached pieces and substrate	C-5b <i>B-72 (3% in xylene, spray applied): 2 coats</i> <i>H₂O (spray applied): 2-3 coats</i> • B-72 consolidates paint surface • H₂O causes swelling and delamination of plaster from substrate • Permits manipulation of deformation • Relaxes cleavage • Does not strengthen bond between large detached pieces and substrate • Appears to lessen the severity of voids
C-5c <i>B-72 (3% in xylene, spray applied): 2 coats</i> <i>H₂O (spray applied): 2-3 coats</i> • B-72 consolidates paint surface • H₂O causes swelling and delamination of plaster from substrate • Permits manipulation of deformation • Relaxes cleavage • Broken portion of outer corner remains detached	C-5d <i>B-72 (3% in xylene, spray applied): 2 coats</i> <i>H₂O (spray applied): 2-3 coats</i> • B-72 consolidates paint surface • H₂O causes swelling and delamination of plaster from substrate • Permits manipulation of deformation • Relaxes cleavage • Appears to lessen the severity of voids

Result of test carried out on three 12-by-12-inch painted multi-layer gypsum board panels designed to treat the loss of adhesion and cohesion of the paint layers without altering the optical properties of the plaster or painting.

Table 14

Surface Consolidation of Powdering Paint with Consolidation and Readhesion	
C-6: 2 ground/finish phases, 2 paintings on 12" gypsum board panel	
C-6a <i>B-72 (3% in xylene, spray applied): 2 coats</i> • B-72 consolidates paint surface	C-6b <i>B-72 (3% in xylene, spray applied): 2 coats</i> • B-72 consolidates paint surface
C-6c <i>B-72 (3% in xylene, spray applied): 2 coats</i> <i>B-67 (3% in mineral spirits, brushed on): 2 coats</i> • B-72 consolidates paint surface • B-67 causes significant surface discoloration • Does not readhere delaminated pieces • Appears to strengthen plaster (intergranular cohesion): pieces previously too fragile to handle without crumbling are now stable enough to be picked up	C-6d <i>B-72 (3% in xylene, spray applied): 2 coats</i> • B-72 consolidates paint surface • Reserved for later research

Result of test carried out on three 12-by-12-inch painted multi-layer gypsum board panels designed to treat the loss of adhesion and cohesion of the paint layers without altering the optical properties of the plaster or painting.

Table 15

Facing Adhesives: Methods and Materials Preparation for <i>Stacco</i> and <i>Strappo</i>			
Adhesive	Adhesive performance	Result of Poultice Application	Final Appearance of Plaster
Colletta (full strength)	• Very viscous • Application repositioned friable surface material • Even distribution required effort • Bonded quickly • Contraction of glue caused delamination from substrate	• Severe swelling of the expansive clays caused by H₂O poultice • Exacerbation of interlayer delamination as well as full-scale separation from the substrate	• Complete reversibility impossible due to deformation and delamination from the substrate • Significant pigment and plaster losses caused by deformation and removal of adhesive residue • Surface slightly yellowed
PVOH (20%)	• Less viscous • Application did not damage surface • Easy to handle • Distributed evenly	• No adverse reaction to H₂O poultice	• Adhesive residue easily removed with H₂O soaked pads • Negligible pigment loss • Surface slightly darkened
Acryloid B-72 (20%)	• Viscous • Application caused some repositioning of friable surface material • Even distribution required minimal effort	• Slight swelling • Separation between layers exhibiting delamination prior to treatment was exacerbated	• Residue removal only partially successful, even after two additional poultice treatments • Pigment loss • Surface is darkened and exhibits a filmy residue
Acryloid B-67 (20%)	• Viscous • Application caused some repositioning of friable surface material • Even distribution required minimal effort	• Significantly longer dwell time for poultice to soften adhesive to an acceptable degree	• Residue removal unsuccessful even after two additional poultice treatments • Pigment loss • Surface is significantly darkened and exhibits an unacceptable sheen

Results of test evaluating the performance of traditional and non-traditional materials used as facing adhesives

Table 16

Facing Adhesives: Methods and Materials Preparation for <i>Stacco</i> and <i>Strappo</i>			
Adhesive	Adhesive performance	Result of Poultice Application	Final Appearance of Plaster
Plextol B500	• Viscous • Application did not damage surface • Easy to handle • Distributed evenly	• No success with acetone/toluene poultice • Adhesive swells but does not resolubilize • Facings stiffened	• Entire layer adhered to facing • Delaminated as a whole
Vinamul 6825	• Viscous • Application did not damage surface • Easy to handle • Distributed evenly	• Limited success with methanol poultice	• Darkened • Uneven filmy residue

Results of test evaluating the performance of traditional and non-traditional materials used as facing adhesives

Table 17

New Support/Backing: Traditional Materials	
Sample E-7 Surface consolidant: none Facing adhesive: <i>Colletta (stacco)</i> Support: hydraulic lime/sand/PVA Removal: H₂O poultice • Clays swelled • Painting detached from new support • Residue removal caused abrasion of paint layer	Sample E-13 Surface consolidant: none Facing adhesive: <i>Colletta (stacco)</i> Support: hydraulic lime/sand/PVA Removal: H₂O poultice • Clays swelled • Poor bond between painting and new support caused extensive loss of plaster and pigment • Residue removal caused abrasion of paint layer
Sample E-14 Surface consolidant: B-72 (3% in toluene) x 1 Facing adhesive: <i>Colletta (strappo)</i> Support: hydraulic lime/sand/PVA Removal: H₂O poultice • Clays swelled • Poor bond between painting and new support and residue removal caused losses of both plaster and pigment	Sample E-15 Surface consolidant: none Facing adhesive: <i>Colletta: (stacco)</i> Support: hydraulic lime/sand/PVA Removal: H₂O poultice • Clays swelled • Poor bond between painting and new support and residue removal caused losses of both plaster and pigment
Sample E-8 Surface consolidant: B-72 (3% in toluene) x 1 Facing adhesive: <i>Colletta: (strappo)</i> Support: hydraulic lime/sand/clay/PVA Removal: H₂O poultice followed by steam • Unnecessary stress on pictorial layer due to severe cracking of support plaster • Inconsistent bond between painting and substrate • Residue removal caused due to abrasion of paint layer	Sample E-10 Surface consolidant: B-72 (3% in toluene) x 1 Facing adhesive: PVOH Support: hydraulic lime/sand /clay/PVA Removal: H₂O poultice • Losses caused by premature removal • Inconsistent bond between painting and substrate
Sample E-11 Surface consolidant: none Facing adhesive: <i>Colletta: (stacco)</i> Support: hydraulic lime/sand/clay/PVA Removal: H₂O poultice followed by steam • Inconsistent bond between painting and substrate	

Result of tests designed to identify an appropriate new support material

Table 18

New Support/Backing: Non-Traditional Support Materials	
Sample E-5 Surface consolidant: none Facing adhesive: <i>Colletta (stacco-100%)</i> Support: plaster support failed, detached painting backed with Plaster of Paris/gauze strips and adhered to foam core with PVA around perimeter Removal: H₂O poultice followed by steam • Failed • Destruction of sample	Sample E-4 Surface consolidant: none Facing adhesive: <i>Colletta (stacco-100%)</i> Support: PVA applied to perimeter of detached painting, adhered to foam core Removal: H₂O poultice followed by steam • Facing could not be removed • Destruction of sample
Sample E-6 Surface consolidant: B-72 (3% in toluene) x 1 Facing adhesive: <i>Colletta (strappo-100%)</i> Support: PVA applied at perimeter of detached painting and adhered to foam core Removal: H₂O poultice followed by steam • Inconsistent bond between painting and substrate • Residue removal caused abrasion of paint layer • Significant superficial checking	Sample E-12 Surface consolidant: none Facing adhesive: <i>Colletta (strappo)</i> Support: foam tape Removal: H₂O poultice • Satisfactory as a temporary support • Painting well adhered to substrate, facilitated facing removal • Slight residue could probably have been removed with steamer
Sample E-9 Surface consolidant: B-72 (3% in toluene) x 1 Facing adhesive: <i>Colletta (strappo)</i> Support: Plasti-Tak Removal: H₂O poultice followed by steam • Worked well as a temporary support • Negligible residue • No evidence of deterioration	

Result of tests designed to identify an appropriate new support material

Table 19

ASTM D4214-89: Chalking Test-Results		
	Test Method A Method D-659	Test Method B Stroke Method
Untreated <i>UT</i>	The chalk mark compares to rating No. 6 in Photographic Reference Standard #1.	The chalk mark compares to rating No. 6 in Photographic Reference Standard #1.
Acryloid B-72 <i>B-72</i>	The chalk mark compares to rating No. 8 in Photographic Reference Standard #1.	The chalk mark compares to rating No. 8 in Photographic Reference Standard #1.
T-1919 <i>ES</i>	The chalk mark compares to rating No. 8 in Photographic Reference Standard #1.	The chalk mark compares to rating No. 8 in Photographic Reference Standard #1.
Aquazol50® /T-1919 + T-1919 <i>AQES</i>	The chalk mark compares to rating No. 8 in Photographic Reference Standard #1.	The chalk mark compares to rating No. 8 in Photographic Reference Standard #1.

Results of chalking test designed to assess affects of treatment on multi-layer painted plaster samples

Table 20

ASTM D3359-90: Measuring Adhesion by Tape Test		
Rating Scale: Test Method A		
5A	No peeling or removal	
4A	Trace peeling or removal along incisions	
3A	Jagged removal along incisions up to $1/16$ in. (1.6mm) on either side	
2A	Jagged removal along most of incisions up to $1/8$ in. (3.2mm) on either side	
1A	Removal from most of the area of the X under the tape	
0A	Removal beyond the area of the X	
Sample	Test Method A.1	Test Method A.2
<i>UT</i>	Rating: 2A	Rating: 1A
<i>B72</i>	Rating: 4A	Rating: 1A
<i>ES</i>	Rating: 4A	Rating: 3A
<i>AQES</i>	Rating: 4A	Rating: 1A

Result of test designed to assess affects of treatment on the adhesive properties of multi-layer painted plaster samples

Table 21

ASTM D3359-90: Measuring Adhesion by Tape Test		
Rating Scale: Test Method B		
5B	The edges of the cuts are completely smooth; none of the squares of the lattice is detached.	
4B	Small flakes of the coating are detached at intersections; less than 5% of the area is affected.	
3B	Small flakes of the coating are detached along edges and at intersections of cuts. The area affected is 5 to 15% of the lattice.	
2B	The coating has flaked along the edges and on parts of the squares. The area affected is 15 to 35% of the lattice.	
1B	The cutting has flaked along the edges of cuts in large ribbons and whole squares have detached. The area affected is 35 to 65 % of the lattice.	
0B	Flaking and detachment worse than Grade 1	
Sample	Test Method B.1	Test Method B.2
UT	Rating: 1B	Rating: 1B
B72	Rating: 2B	Rating: 1B
ESB72	Rating: 4B	Rating: 3B
AQESB72	Rating: 3B	Rating: 2B

Result of test designed to assess affects of treatment on the adhesive properties of multi-layer painted plaster samples

Table 22

CRATerre Water Resistance Data: Untreated				
Sample	Time Elapsed (minutes)	Pigment loss (mm)	Plaster loss (mm)	Depth of erosion (no. of layers affected)
<i>UT-1</i>	10	6mm	-	-
	20	12.5mm	2mm	1
	30	18mm	3mm	1
	40	18mm	5mm	4
	50	19mm	18mm	6
	60	22mm	20mm	6
	70	25mm	25mm	8
	80	30mm	25mm	10
	90	30mm	30mm	12
	100	30mm	30mm	12
	110	30mm	30mm	12
	120	30mm	30mm	13

Table 23

CRATerre Water Resistance Data: Untreated				
Sample	Time Elapsed (minutes)	Pigment loss (mm)	Plaster loss (mm)	Depth of erosion (no. of layers affected)
<i>UT-2</i>	10	17.5mm	-	-
	20	20mm	-	-
	30	22mm	-	-
	40	24mm	3mm	1
	50	24mm	3.4mm	1
	60	25mm	7mm	2
	70	25mm	11mm	2
	80	26mm	15.4mm	2
	90	26mm	19mm	5
	100	26mm	20.6mm	6
	110	26mm	25.1mm	6
	120	26mm	26mm	8

Results of test to assess the water resistance of treated and untreated samples

Table 24

CRATerre Water Resistance Data: Consolidated				
Sample	Time Elapsed (minutes)	Pigment loss (mm)	Plaster loss (mm)	Depth of erosion (no. of layers affected)
<i>ES-1</i>	10	9mm	-	-
	20	15mm	-	-
	30	16mm	-	-
	40	16mm	2mm	1
	50	16mm	5.1mm	1
	60	20mm	10mm	1
	70	20mm	10mm	1
	80	20mm	10.2mm	1
	90	20mm	10.3mm	2
	100	20mm	10.3mm	2
	110	20mm	10.4mm	2
	120	20mm	10.5mm	3

Table 25

CRATerre Water Resistance Data: Consolidated				
Sample	Time Elapsed (minutes)	Pigment loss (mm)	Plaster loss (mm)	Depth of erosion (no. of layers affected)
<i>ES-2</i>	10	-	-	-
	20	-	-	-
	30	-	-	-
	40	-	-	-
	50	-	-	-
	60	-	-	-
	70	1mm	-	1
	80	2mm	-	1
	90	2mm	-	1
	100	2mm	-	1
	110	2mm	-	1
	120	2mm	-	1

Results of test to assess the water resistance of treated and untreated samples

Table 26

CRATerre Water Resistance Data: Preconsolidant + Consolidant				
Sample	Time Elapsed (minutes)	Pigment loss (mm)	Plaster loss (mm)	Depth of erosion (no. of layers affected)
<i>AQES-1</i>	10	-	-	-
	20	2mm	-	1
	30	3mm	-	1
	40	7.5mm	-	1
	50	10mm	-	1
	60	10mm	-	1
	70	12mm	-	1
	80	15mm	-	1
	90	16mm	-	1
	100	16mm	-	1
	110	16mm	-	1
	120	16mm	-	1

Table 27

CRATerre Water Resistance Data: Preconsolidant + Consolidant				
Sample	Time Elapsed (minutes)	Pigment loss (mm)	Plaster loss (mm)	Depth of erosion (no. of layers affected)
<i>AQES-2</i>	10	-	-	-
	20	-	-	-
	30	-	-	-
	40	-	-	-
	50	0.5mm	-	1
	60	0.5mm	-	1
	70	0.5mm	-	1
	80	0.5mm	-	1
	90	0.7mm	-	1
	100	0.7mm	-	1
	110	1mm	-	1
	120	1mm	-	1

Results of test to assess the water resistance of treated and untreated samples

Table 28

Compatibility of Treatments	
<i>Colletta: Stacco facings (50% in H₂O)</i>	
Sample D-1 <i>Surface consolidant: B-72 (3% in Toluene) 2 spray applications</i> <i>Preconsolidant: H₂O</i> <i>Facing Adhesive: Colletta (stacco-50%)</i> • Effortless full-scale detachment of plaster stratum from substrate • Slightly darkened • Simple, clean removal of facing with steamer • Interlayer separation • Irregular cracking • Superficial checking	Sample D-4 <i>Surface consolidant: B-72 (3% in Toluene) 2 spray applications</i> <i>Preconsolidant: Aquazol 50® / H₂O (5%)</i> <i>Facing Adhesive: Colletta (stacco-50%)</i> • Slightly yellowed • Minor losses caused by premature facing removal • Interlayer separation • Irregular cracking
Sample D-19 <i>Preconsolidant: Aquazol 50® / H₂O (5%)</i> <i>Surface consolidant: Blair Spray Fix</i> <i>Facing Adhesive: Colletta (stacco-50%)</i> • Yellowed • Residue of facing adhesive remains on surface • Some loss of plaster due to premature facing removal ($\pm 5\%$) • Use of steamer facilitated removal after preliminary losses • Interlayer separation • Irregular cracking	

Evaluation of the compatibility of materials used for surface consolidation, preconsolidation and facing adhesion

Table 29

Compatibility of Treatments	
<i>Colletta: Strappo facings (75% in H₂O)</i>	
Sample D-2 <i>Surface consolidant: B-72 (3% in Toluene) 2 spray applications</i> <i>Preconsolidant: H₂O</i> <i>Facing Adhesive: Colletta(strappo- 75%)</i> • Slightly yellowed • Negligible losses • Irregular cracking	Sample D-3 <i>Surface consolidant: B-72 (3% in Toluene) 2 spray applications</i> <i>Preconsolidant: Aquazol 50® / H₂O (5%)</i> <i>Facing Adhesive: Colletta(strappo- 75%)</i> • Most of painting detached prior to manipulation due to contraction of the glue • Unacceptable powdery losses of both plaster and pigment ($\pm 20\%$) • Significant areas of plaster swelled and disintegrated after the application of a H₂O poultice (damage attributed to H₂O rather than premature facing removal because plaster disintegrated rather than peeling off with the gauze) • Slight residue, damage halted removal
Sample D-18 <i>Surface consolidant: H₂O</i> <i>Fixative: Blair Spray Fix</i> <i>Facing Adhesive: Colletta (strappo-75%)</i> • Most of painting detached prior to manipulation due to contraction of the glue • Slight yellowing • Partial disintegration of plaster due to H₂O poultice (losses only reach to next layer) • Plaster and pigment loss ($\pm 15\%$) • Significant interlayer separation • Slight residue	Sample D-21 <i>Surface consolidant: B-72 (3% in Toluene) 11 spray applications</i> <i>Facing Adhesive: Colletta (strappo-75%)</i> • Most of painting detached prior to manipulation due to contraction of the glue • Full-scale detachment from substrate

Evaluation of the compatibility of materials used for surface consolidation, preconsolidation and facing adhesion

Table 30

Compatibility of Treatments	
PVOH facings (25% in H ₂ O)	
Sample D-5 Surface consolidant: B-72 (3% in Toluene) 2 spray applications Preconsolidant: H₂O Facing Adhesive: PVOH (25%) • Effortless detachment • Ground layer remained attached to substrate • Slight discoloration • Negligible pigment loss	Sample D-6 Surface consolidant: B-72 (3% in Toluene) 2 spray applications Preconsolidant: Aquazol 50® / H₂O (5%) Facing Adhesive: PVOH (25%) • Negligible loss of plaster and pigment ($\pm 2\%$) • Slight darkening • Irregular cracking • Superficial checking
Sample D-12 Surface consolidant: B-72 (3% in Toluene) 11 spray applications Facing Adhesive: B-72 8%, later removed Facing Adhesive II: PVOH (25%) • Removal made somewhat more difficult due to prior application of B-72 (8%) • Duration of poultice treatment was significantly increased before the adhesive softened to an acceptable degree	Sample D-17 Surface consolidant: Blair Spray Fix Facing Adhesive: PVOH (25%) • Simple removal using H₂O poultice (quick resolubilization of the adhesive allows for removal of the facing before significant deterioration of the plaster can occur) • Negligible discoloration • Irregular cracking

Evaluation of the compatibility of materials used for surface consolidation, preconsolidation and facing adhesion

Table 31

Compatibility of Treatments	
Plextol B500 / Vinamul 6825 facings	
Sample D-7 <i>Surface consolidant: B-72 (3% in Toluene) 2 spray applications</i> <i>Preconsolidant: Aquazol 50® / H₂O (5%)</i> <i>Facing Adhesive: Plextol B500</i> • All attempts at removal failed	Sample D-9 <i>Surface consolidant: B-72 (3% in Toluene) 2 spray applications</i> <i>Preconsolidant: H₂O</i> <i>Facing Adhesive: Plextol B500</i> • All attempts at removal failed
Sample D-8 <i>Surface consolidant: B-72 (3% in Toluene) 2 spray applications</i> <i>Preconsolidant: Aquazol 50® / H₂O (5%)</i> <i>Facing Adhesive: Vinamul 6825</i> Significant darkening • Extensive destruction of plaster (application of the alcohol-based solvent dissolved the foam tape, the adhesive, and the foam core support) • Unacceptable deformation and cracking of plaster • Straw component in underlying plaster layers may have exacerbated some of the difficulties	Sample D-10 <i>Surface consolidant: B-72 (3% in Toluene) 2 spray applications</i> <i>Preconsolidant: H₂O</i> <i>Facing Adhesive: Vinamul 6825</i> • Partial disintegration of plaster • Residue removal abraded paint surface • Residue of adhesive remains on surface • Application of alcohol-based solvent dissolved the adhesive of the foam tape support • Deterioration of the support material left little to stabilize plaster • Irregular cracking • Flaking

Evaluation of the compatibility of materials used for surface consolidation, preconsolidation and facing adhesion

Table 32

Results of Final Detachment Tests		
Sample	Treatment	Final Result and Appearance
Sample A	Surface consolidant: B-72 (3% in toluene) x 8 Preconsolidant: H ₂ O Facing Adhesive: <i>Colletta</i> (stacco-50%)	• Indiscriminate detachment • Remaining layers fragmented • Slight, irregular surface cracking • Slightly darkened • Losses: negligible • Slight adhesive residue
Sample B	Surface consolidant: B-72 (3% in toluene) x 8 Preconsolidant: H ₂ O Facing Adhesive: PVOH (20% in H ₂ O)	• Indiscriminate detachment • Remaining layers fragmented • Slight, irregular surface cracking • Slightly darkened • Losses: negligible • Slight adhesive residue • Some deformation and interlayer separation due to swelling of plasters
Sample C	Surface consolidant: B-72 (3% in toluene) x 8 Preconsolidant: H ₂ O Facing Adhesive: PVOH (20% in H ₂ O)	• Indiscriminate detachment • Remaining layers fragmented • Slight, irregular surface cracking • Slightly darkened • Losses: significant, appear as powdery surface • Slight adhesive residue • Some interlayer detachment due to swelling of plasters
Sample D	Surface consolidant: B-72 (3% in toluene) x 8 Preconsolidant: H ₂ O Facing Adhesive: <i>Colletta</i> (stacco-50%)	• Most of painting detached prior to manipulation due to contraction of glue • Indiscriminate detachment • Remaining layers fragmented • Slight, irregular surface cracking • Slightly darkened • Losses: negligible; concentrated around edges • Slight adhesive residue • Some interlayer detachment due to swelling of plasters
Sample G ₁	Surface consolidant: B-72 (3% in toluene) x 1 Preconsolidant: * Consolidant: T-1919 Facing Adhesive: PVOH (20% in H ₂ O)	• Indiscriminate detachment • Remaining layers fragmented • Slight, irregular surface cracking • Slight darkening on consolidation • Losses: negligible (slight powdering) • Slight adhesive residue, attempts at removal caused abrasion of paint layer

Table 33

Results of Final Detachment Tests		
Sample	Treatment	Final Result and Appearance
Sample G ₂	Surface consolidant: B-72 (3% in toluene) x 1 Preconsolidant: * Consolidant: T-1919 Facing Adhesive: <i>Colletta</i> (stacco-50%)	• Indiscriminate detachment • Remaining layers fragmented • Slight, irregular surface cracking • Slight darkening on consolidation • Losses: significant, approx. 15%
Sample H	Surface consolidant: B-72 (3% in toluene) x 8 Preconsolidant: H ₂ O Facing Adhesive: <i>Colletta</i> (strappo-75%)	• Most of painting detached prior to manipulation, due to contraction of glue • Indiscriminate detachment • Remaining layers fragmented • Slight irregular surface cracking • Slightly darkened • Losses: significant; concentrated around edges • Slight adhesive residue • Some deformation and interlayer separation due to swelling of plasters
Sample I	Surface consolidant: B-72 (3% in toluene) x 8 Preconsolidant: H ₂ O Facing Adhesive: <i>Colletta</i> (strappo-75%)	• Most of painting detached prior to manipulation due to contraction of glue • Indiscriminate detachment • Remaining layers fragmented • Losses: negligible, concentrated around edges; powdery • Slight adhesive residue • Some deformation and interlayer separation due to swelling of plasters
Sample J ₁	Surface consolidant: B-72 (3% in toluene) x 1 Preconsolidant: H ₂ O Consolidant T-1919 Facing Adhesive: PVOH (20% in H ₂ O)	• Most of painting (approx. 95%) detached between 13th and 14th layers (most strappo-like) behavior • Slight darkening on consolidation • Losses: negligible • Slight adhesive residue; attempts at removal caused abrasion of paint surface
Sample J ₂	Surface consolidant: B-72 (3% in toluene) x 1 Preconsolidant: H ₂ O Consolidant: T-1919 Facing Adhesive: <i>Colletta</i> (stacco-50%)	• Most of painting detached prior to manipulation due to contraction of glue • Remaining layers fragmented • Slight darkening on consolidation • Losses: negligible (approx. 7%) concentrated around edges • Slight adhesive residue

Table 34

% Distribution of Each Layer Remaining on Substrate After Detachment:										
Sample	A <i>Stacco</i>	B PVOH	C PVOH	D <i>Stacco</i>	G ₁ AQES/ PVOH	G ₂ AQES/ <i>Stacco</i>	H <i>Strappa</i>	I <i>Strappa</i>	J ₁ T-1919/ PVOH	J ₂ T-1919/ <i>Stacco</i>
Layer 13	-	-	2.0%	16.0%	76.0%	-	10.0%	-	94.5%	-
Layer 12	-	-	3.0%	28.0%	-	-	-	-	1.0%	-
Layer 11	-	1.0%	-	45.0%	1.0%	-	1.0%	53.0%	-	19.0%
Layer 10	-	2.0%	4.0%	-	1.0%	-	10.0%	-	2.0%	-
Layer 9	31.0%	15.0%	4.0%	0.5%	1.0%	-	3.0%	-	-	-
Layer 8	7.0%	35.0%	2.0%	-	-	-	20.0%	1.0%	-	-
Layer 7	6.0%	-	35.0%	2.0%	-	-	10.0%	5.5%	-	-
Layer 6	0.5%	25.0%	-	8.0%	-	-	20.0%	5.5%	2.0%	41.0%
Layer 5	3.0%	4.0%	-	-	-	-	2.0%	35.0%	-	5.0%
Layer 4	0.5%	1.0%	-	-	1.0%	2.5%	8.0%	-	0.5%	3.0%
Layer 3	-	-	-	-	15.0%	21.0%	8.0%	-	-	-
Layer 2	1.0%	14.0%	40.0%	0.5%	5.0%	0.5%	1.0%	-	-	26.0%
Layer 1	36.0%	-	-	-	-	75.0%	7.0%	-	-	-
Terra cotta	15.0%	3.0%	10.0%	-	-	1.0%	-	-	-	6.0%

Table 35

Results of ASTM Cracking, Flaking and Checking Tests				
Sample	Treatment	Rating		
		Cracking	Flaking	Checking
Untreated	N/A	Type 1: Irregular Rating: 8	Rating 8	Rating 8
A <i>Stacco</i>	Surface consolidant: B-72 (3% in toluene) x 8 Preconsolidant: H ₂ O Facing adhesive: <i>Colletta (stacco-50%)</i>	Type 1: Irregular Rating: 6	Rating: 6	Rating: 6
B PVOH	Surface consolidant : B-72 (3% in toluene) x 8 Preconsolidant: H ₂ O Facing adhesive: PVOH (20% in H ₂ O)	Type 1: Irregular Rating: 6	Rating: 4	Rating: 8
C PVOH	Surface consolidant: B-72 (3% in toluene) x 8 Preconsolidant: H ₂ O Facing adhesive: PVOH (20% in H ₂ O)	Type 1: Irregular Rating: 6	Rating: 2	Rating: 8
D <i>Stacco</i>	Surface consolidant: B-72 (3% in toluene) x 8 Preconsolidant: H ₂ O Facing adhesive: <i>Colletta (stacco-50%)</i>	Type 1: Irregular Rating: 6	Rating: 6	Rating: 8
G ₁ AQES/ PVOH	Surface consolidant: B-72 (3% in toluene) x 1 Preconsolidant: 50/50(v/v)Aquazol (5% in EtOH)+ T-1919 Consolidant: T-1919 Facing adhesive: PVOH (20% in H ₂ O)	Type 1: Irregular Rating: 8	Rating: 6	Rating: 8
G ₂ AQES/ <i>Stacco</i>	Surface consolidant: B-72 (3% in toluene) x 1 Preconsolidant: 50/50(v/v)Aquazol (5% in EtOH)+ T-1919 Consolidant: T-1919 Facing adhesive: <i>Colletta (stacco-50%)</i>	Type 1: Irregular Rating: 6	Rating: 4	Rating: 8

Table 36

Results of ASTM Cracking, Flaking and Checking Tests				
Sample	Treatment	Rating		
		Cracking	Flaking	Checking
Untreated	N/A	Type I: Irregular Rating: 8	Rating: 8	Rating: 8
H <i>Strappo</i>	Surface consolidant: B-72 (3% in toluene) x 8 Preconsolidant: H ₂ O Facing adhesive: <i>Colletta (strappo-75%)</i>	Type 1: Irregular Rating: 4	Rating: 4	Rating: 8
I <i>Strappo</i>	Surface consolidant: B-72 (3% in toluene) x 8 Preconsolidant: H ₂ O Facing adhesive: <i>Colletta (strappo-75%)</i>	Type 1: Irregular Rating: 6	Rating: 4	Rating: 8
J ₁ T-1919/ PVOH	Surface consolidant: B-72 (3% in toluene) x 1 Preconsolidant: H ₂ O Consolidant: T-1919 Facing adhesive: PVOH (20% in H ₂ O)	Type 1: Irregular Rating: 8	Rating: 6	Rating: 8
J ₂ T-1919/ <i>Stacco</i>	Surface consolidant: B-72 (3% in toluene) x 1 Preconsolidant: H ₂ O Consolidant: T-1919 Facing adhesive: <i>Colletta (stacco-50%)</i>	Type 1: Irregular Rating: 4	Rating: 6	Rating: 8

Table 37

Munsell Color Notations: Before and After Treatment							
Sample A: <i>Stacco</i>				Sample B: <i>PVOH</i>			
	White	Red	Black		White	Red	Black
Untreated	N9.25/ N9.5/	2.5R 6/4 5R 5/4	N2.25/- N3.25/	Untreated	N9.5/	2.5R 6/4 5R 5/4	N2.0/- N4.0/
Treated	5Y 9/1	7.5R 4/4 7.5R 5/4 7.5R 6/4	N2.25/- N3.5/	Treated	N9.5/	5R 4/6 5R 5/6 7.5R 6/6 7.5R 7/4	N2.75/- N3.25/
Sample C: <i>PVOH</i>				Sample D: <i>Stacco</i>			
	White	Red	Black		White	Red	Black
Untreated	N9.5/	7.5R 5/6 7.5R 6/6	N2.0/- N4.0/	Untreated	N9.5/	7.5R 5/6 7.5R 6/6	N2.0/- N4.0/
Treated	N9.5/	7.5R 6/4 7.5R 4/4	N2.75/- N3.0/	Treated	5Y 9/1	7.5R 4/6 7.5R 5/6	N2.75/- N3.25/
Sample G: <i>AQES/PVOH</i>				Sample G: <i>AQES/Stacco</i>			
	White	Red	Black		White	Red	Black
Untreated	N9.5/	7.5R 5/6 7.5R 6/6	N2.0/- N4.0/	Untreated	N9.5/	7.5R 5/6 7.5R 6/6	N2.0/- N4.0/
Treated G ₁	5Y 9/1	10R 4/6 10R 5/6	N2.75/ N3.25/ N4.25/	Treated G ₂	5Y 9/1	10R 4/6 10R 6/6	N2.75/- N3.25/
Sample H: <i>Strappo</i>				Sample I: <i>Strappo</i>			
	White	Red	Black		White	Red	Black
Untreated	N9.25/ N9.5/	7.5R 5/6 7.5R 6/6	N2.25/- N3.5/	Untreated	N9.5/	7.5R 5/6 7.5R 6/6	N2.0/- N4.0/
Treated	5Y 9/1	10R 4/6 10R 5/6	N2.75/- N3.25/	Treated	5Y 9/1	10R 4/6 10R 5/6	N3.0/- 3.25/
Sample J: <i>T-1919/PVOH</i>				Sample J: <i>T-1919/Stacco</i>			
	White	Red	Black		White	Red	Black
Untreated	N9.5/	7.5R 5/6 10R 7/4	N2.75/- N3.5/	Untreated	N9.5/	7.5R 5/6 10R 7/4	N2.75/- N3.5/
Treated J ₁	5Y 9/1	10R 4/6 10R 5/6	N2.75/ N3.25/	Treated J ₂	5Y 9/1	10R 4/6 10R 6/6	N2.75/- N3.25/

Key:

- Samples are listed with facing adhesives
- AQES refers to samples preconsolidated with the Aquazol50®/T-1919 mixture, then consolidated with T-1919
- T-1919 refers to those samples preconsolidated with T-1919

Table 38

Munsell Color Notations: Interpretation										
Sample		Hue			Value			Chroma		
		+	=	-	+	=	-	+	=	-
A <i>Stacco</i>	Unpainted	X					X		X	
	Red	X				X			X	
	Black		X				X			
B <i>PVOH</i>	Unpainted		x			X			X	
	Red	X					X	X		
	Black		x			X				
C <i>PVOH</i>	Unpainted		X			X			X	
	Red		X				X			X
	Black		X			X				
D <i>Stacco</i>	Unpainted	X					X		X	
	Red		X			X			X	
	Black		X			X				
G₁ <i>AQES/</i> <i>PVOH</i>	Unpainted	X					X		X	
	Red	X			X				X	
	Black		X				X			
G₂ <i>AQES/</i> <i>Stacco</i>	Unpainted	X					X		X	
	Red	X			X				X	
	Black		X				X			
H <i>Strappo</i>	Unpainted	X					X		X	
	Red	X			X				X	
	Black		X				X			
I <i>Strappo</i>	Unpainted	X					X		X	
	Red	X					X		X	
	Black		X				X			
J₁ <i>T-1919/</i> <i>PVOH</i>	Unpainted	X					X		X	
	Red	X					X	X		
	Black		X				X			
J₂ <i>T-1919/</i> <i>Stacco</i>	Unpainted	X					X		X	
	Red	X					X	X		
	Black		X				X			

Key:

- Samples are listed along with facing adhesives
- AQES refers to samples preconsolidated with Aquazol50®/T-1919, and then consolidated with T-1919
- T-1919 refers to those samples consolidated with T-1919
- (+) in hue column refers to yellowing of the surface
- = color stayed the same
- - color lightened

4.3 Conclusions

Two systems of treatment were successful for strengthening the paint and plaster surfaces and facilitating detachment of the mural paintings. The first two steps were the same for each: surface consolidation of the painted plaster with an acrylic resin, Acryloid B-72, followed by preconsolidation using water combined with the application of pressure. The use of Acryloid B-72 as a surface consolidant yielded excellent results. Multiple spray applications of a 3% solution in toluene strengthened the surface without altering the optical properties of the plaster or paintings, and did not interfere with subsequent treatment. Furthermore, Acryloid B-72 made the painted surface insoluble in water, which allowed for preconsolidation of the clay-based renders using aqueous materials. Results of the experimental program revealed that water facilitated the manipulation of deformation and cleavage, and increased adhesion between layers.

The third step, application of a facing adhesive for mural detachment, varied between the two systems. For one, *colletta* was used, and for the other, polyvinyl alcohol. Facings for mural painting detachment must provide consistent coverage to all the painted surface and adequate support to the detached mural painting without penetration of the plaster. *Colletta*, a collagen-based adhesive traditionally used for the detachment of paintings on lime-based plasters, and polyvinyl alcohol, an adhesive previously tested in the American Southwest for the detachment of paintings on earthen plaster, were successful at each of the objectives. They permitted easy removal of the facing materials and residue and were not adversely affected by other forms of treatment.

4.4 Recommendations for further research

Additional research focusing on materials characterization and analysis is recommended.

- Identification of the clay component within the plasters has yet to be carried out.
- Further analysis for organic materials using more advanced techniques such as FTIR, GC-MS, and HPLC is recommended. A wide sampling of materials from various locations should be analyzed with these and other methods for the identification of organic binding media. A comprehensive understanding of the paint and plaster technology is critical to interpretation and conservation of the site.
- Prior to the detachment of paintings on site, continued efforts should be made to identify an appropriate new support material. Preservation of the detached painting and the integrity of its original surface are dependent upon the selection of a stable support material. Additional testing should consider modified lime and clay supports as well as lightweight support materials such as expanded PVC or epoxy type foam resins. Because a poor bond to the new support caused some of the deterioration exhibited by the detached paintings, it may be valuable to reassess the performance of pretreatment and detachment techniques using a more suitable system of support.
- Although positive results were obtained using ethyl silicates to consolidate the clay plasters, they were unremarkable and required a stable environment. Further testing may be necessary to identify a more suitable consolidant system proven effective in areas of low relative humidity.

Tests showed excellent results for systems developed to pretreat and detach paint layers on earthen plasters using the *stacco* method. At the present time, facsimile testing indicates that it is not yet possible to perform a controlled detachment of discrete layers or sequences of painted plaster to a consistent depth. However, since the research was carried out exclusively on laboratory facsimiles, the evaluation of all treatments, particularly detachment techniques should be reassessed *in situ*. The ability to detach expansive clay-based plasters with weakened pictorial layers without significant losses within the paint layer is encouraging. Additional research and *in situ* testing may help to answer the questions that remain.

Appendix A: Çatalhöyük Treatment History

Wall paintings excavated by James Mellaart in the 1960s were conserved, detached and stored at the Ankara Museum. The following is a summary of treatments as described by Pamela French in reports dating from 1968-1974.¹⁵³

Plaster and pigment characterization

Microscopical examination of one plaster sample was reported. Clay and paint sample analyses were carried out on a binocular microscope at forty times magnification. The sample examined was found to have approximately ten layers of plaster with grass lacunae in the ground layers. The thickness of the preparatory layer was inconsistent, with variations of up to three millimeters in some sections. Traces of red-brown, red, and black paint were visible in all the layers.

Chemical spot tests were conducted to help characterize the plaster and pigments, and to detect the presence of salts. Tests for calcium carbonate content indicated that the plaster was made from a highly calcareous clay. Iron was detected in analyses of both the

¹⁵³ Pamela French, "Clay and Paint Samples: Preliminary Testing," "Report on Work Carried Out on the Murals from Çatal Hüyük in the Archaeological Museum, Ankara, in September 1968," "Report to the British Academy on the Work Done on the Çatal Hüyük Paintings," "The Çatal Hüyük Wall-Paintings," "The Continuation of the Conservation of the Çatal Hüyük Wall Paintings Undertaken in the Museum of Anatolian Cultures, Ankara, Summer, 1973," and "Report to the British Academy on the Conservation of the Çatal Hüyük Wall Paintings, Summer 1973, Spring 1974." (n.p., n.d.)

red-brown pigment and a section of unpainted clay plaster.¹⁵⁴ Tests for salt content indicated high percentages of nitrates, phosphates, and chlorides.

An area of red-brown painted plaster was tested for the presence of blood. Positive staining occurred, but results were inconsistent throughout the layer. Although blood may have been used as a pigment, binder, or wall coating, further testing was recommended.

Detachment techniques

Three types of detachment were used:

- Detachment of the paint layer, underlying plaster, and mud brick wall support: the block method,
- Detachment of the paint layer and the mud plaster support, and
- Detachment of the paint layer alone: the peeling method

In each technique, a fine muslin or linen facing was applied to the painted surface with size or bone glue.

Field Treatment

Following excavation, paintings and reliefs were cleaned *in situ* and consolidated with polyvinyl acetate emulsion. A two-layer facing of Japanese tissue and fine linen was applied to each section with size and permitted to dry for three days. Paint layers were peeled away with some mud plaster still adhering. The back of each painting was impregnated with polyvinyl acetate emulsion. Because it did not penetrate to the paint

¹⁵⁴ Both tests were conducted using potassium ferrocyanide.

layer, an intermediate layer of unconsolidated plaster remained between the two treated surfaces.

Evaluation of detached paintings and reliefs

Unmounted paintings detached by the block method in 1962 and 1963 were evaluated in 1968. They were in poor condition and deteriorating rapidly.

The following conditions were identified:

- Most of the painted surfaces did not have facings.
- The synthetic resin used to consolidate the paint, probably polyvinyl acetate, had contracted, causing severe flaking.
- Losses within the paint layer were caused by disintegration of the supporting plaster.
- Paintings with facings showed slightly less deterioration.

Careful packing preserved paintings detached during the 1965 season.

Overcrowding and repeated fluctuations in temperature and humidity in the storeroom caused deterioration.

Most of the mounted paintings treated between 1962 and 1965 exhibited the following conditions:

- Loss of adhesion between the paint layer and the support plaster
- Loss of adhesion between the consolidated paint layer and the unconsolidated support
- Disintegration of the mud plaster support behind the consolidated paint layer

- Discoloration of the paint surface due to deterioration of the polyvinyl acetate consolidant

In all cases in which an intermediate layer of unconsolidated plaster remained between the inner and outer surfaces of a detached painting, differences between the rates of contraction and expansion of the various layers caused it to crumble. The unsupported paint layer became severely deteriorated. Attempts to fully consolidate mud plaster remaining behind the paint layer by inducing the PVA to penetrate completely were unsuccessful. Partial solubility of the emulsion after the application of solvents indicated that partial cross-linking of the polymer might have occurred. Because the gel-like emulsion could not be induced to penetrate, it had to be mechanically removed from the backs of the paintings.¹⁵⁵ It was decided that the best way to preserve the detached paintings was to remove most, if not all plaster adhering to the paint layer in order to prevent the creation of an unconsolidated middle zone between the paint layer and the rear surface of the plaster.

Retreatment

Retreatment of detached paintings and reliefs was carried out between 1968 and 1973. Sections with unconsolidated plaster still remaining were reduced to a thickness of approximately one to three millimeters. Multiple applications of polymethyl methacrylate, at concentrations ranging from 0.5%-15% were used to consolidate the backs of the paintings and reliefs.

Backing

Following consolidation, it was necessary to identify a strong backing material that would remain flexible and reversible. A material with the same density as the mud plaster was desired. A three-part backing system was developed:

- First layer: 1.5 parts polymethyl methacrylate, 40% in toluene; 1 part marble powder; 0.5 parts flaked silica;
- Second layer: 1 part polymethyl methacrylate, 40% in toluene; 1 part marble powder; 0.5 parts flaked silica; 0.5 parts glass fibers for strength;
- Third layer: identical to the first, used as an adhesive for strips of pre-washed cotton muslin applied in a criss-cross pattern.

Facing Removal

Facings were removed easily using very hot water applied with sheets of foam rubber.

Surface Cleaning

Attempts to remove the polyvinyl acetate consolidant with solvents resulted in a partially solubilized gel. The greatest degree of solubility was attained with a 50/50 solution of amylacetate and acetone applied with swabs. Removal of the gel caused the loss of pigment particles. Compresses of blotting paper or cotton and muslin saturated with solvent were applied repeatedly to remove the gel without sacrificing too much of the pigment.

¹⁵⁵ Additional testing showed that even penetration could not be guaranteed beyond a depth of 1.5-2.0

Consolidation

Painted surfaces were re-consolidated with multiple applications of polymethyl methacrylate, in solutions ranging from 3% to 5% in toluene. Heat was used to induce solvent evaporation, to prevent the back from being affected.

Primary support of relief plasters

Requirements for a primary mounting material were reversibility, simplicity, and for reliefs, a form of incorporated support. Limited success with expanded polystyrene led to the temporary use of a plaster cast support for raised areas. Plasticine was used to form an edging around the painted relief. Vaseline was used as an isolating layer to coat the back. A plaster made with a solution of 25% polyvinyl acetate emulsion and glass fibers was poured into the edged relief. Once dry, it was trimmed to the appropriate thickness. The Vaseline isolating layer allowed for easy separation from the painted relief. Plaster casts were replaced by expanded polyurethane foam as the more appropriate support for relief areas prior to application of a rigid support.

Mounting of relief plasters

A material similar in appearance to the wall plaster was needed to fill the area around mounted sections and link them together. Sheets of expanded polystyrene were adhered to a wooden frame with polyvinyl acetate emulsion. A space the size of the detached pieces was hollowed out of the polystyrene and the detached plasters fitted within them. Holes were drilled in areas of unpainted plaster, and the reliefs with their

millimeters.

plaster supports were screwed to wooden mounts. Polystyrene was painted to blend in with the mud. Losses were inpainted with Rowney Cryla Colors.

Mounting of peeled paintings

Peeled paintings were backed with the same primary material used for the relief plasters. Plaster supports were not needed in the case of paintings. Expanded polystyrene sheets, capable of supporting raised and buckled areas, were used with wooden trays to mount the paintings. Paintings were screwed in as before. The polystyrene and any pigment losses were inpainted with Rowney Cryla Colors.

Rigid support for exhibition

The most successful rigid support for exhibition was found to be a combination of polyester resin, glass fibers, and expanded aluminum applied to the existing backing.

1972: Evaluation of sections treated in 1968 and 1969

Results of an evaluation of treatments carried out in 1968 and 1969 were positive. The synthetic resin remained reversible and showed no apparent alteration. Support materials were well adhered to paint layers. The aging of the consolidant did not alter the optical properties of the paint layers.

Appendix B: Overview of Techniques

Introduction

Wall paintings, unlike easel paintings, are integral parts of the architecture to which they have been applied. The significance of this association is apparent by the inevitable loss of context that occurs when a painting has been detached. For this reason, it is imperative that detachment occur only as a last resort when there are no other treatment options. Archaeological excavation poses just such an example. Mural detachment is one and sometimes the only means of prolonging the survival of paintings which would otherwise be destroyed during excavation.

Detachment methods for the transfer of mural paintings have been documented since antiquity. Three techniques were originally developed for the detachment of frescoes-paintings executed on fresh moist plaster which become chemically bonded to the lime ground:

- *Stacco a massello*, the oldest, refers to the removal of the painting along with its rendering and all or part of the wall to which it has been applied.
- *Stacco* refers to a technique that removes the paint layer along with its immediately underlying plaster layers.
- *Strappo*, the most delicate of the operations, requires the lifting of the paint layer alone.

In order to illustrate these techniques, the remainder of this overview will trace their use through time in a brief historical summary and selection of case studies arranged by material.

Historical Background

Accounts of wall painting detachment go back to at least the first century B.C. As noted in *The Ten Books on Architecture* by Vitruvius, “In Sparta, paintings have been taken out of certain walls by cutting through the bricks, then have been placed in wooden frames, and so brought to the Comitium to adorn the aedileship of Varro and Murena.”¹⁵⁶ Caligula’s attempts to remove wall paintings from Lanuvium were cited by Pliny the Elder in the first century A.D., in the 35th volume of *Historia Naturalis*. “Similarly at Lanuvium, where there are an Atalanta and a Helena close together, nude figures, painted by the same artist, each of outstanding beauty (the former shown as a virgin), and not damaged even by the collapse of the temple. The Emperor Caligula from lustful motives attempted to remove them, but the consistency of the plaster would not allow this to be done.”¹⁵⁷ These accounts illustrate motives for removal as well as the lack of concern for context that prevailed once the technology was mastered.

The use of detachment techniques is believed to have declined with the Roman Empire until their rediscovery by the Italians in the fifteenth century.¹⁵⁸ Although amateur removals were attempted frequently throughout the interim, they were generally unsuccessful. By the fifteenth century, frescoes at risk of destruction by demolition, particularly those with religious subject matter, were moved along with their supporting

¹⁵⁶ Marcus Vitruvius Pollio, *The Ten Books on Architecture*, trans. Morris Hicky Morgan (New York: Dover Publications, Inc. 1960) 53.

¹⁵⁷ Pliny the Elder, Gaius Plinius Secundus, *Natural History, Book XXXV*, trans. H. Rackham (Massachusetts: Harvard University Press, 1995) 273.

walls. In 1480, the *Resurrection* by Piero della Francesca was removed along with the layer of bricks on which it had been painted to the Palazzo Communale of Sansepolcro.¹⁵⁹ In *Vita des Spinello Aretino*, Giorgio Vasari described the 1501 removal of a Spinello Aretino fresco. Entire wall sections held together with chains were cut away in order to detach a painting of the Madonna about to be demolished at the old cathedral and oratory of Santo Stefano in Arezzo. The mural, fastened with rope, was transported to a new church in October 1561.¹⁶⁰ Vasari also cited the removal of Ghirlandaio's *St. Jerome* and Botticelli's *St. Augustine* in Ognisanti in Florence.¹⁶¹ The frescoes were bound with iron and transported by friars without damage when the old choir of the church of Ognisanti was destroyed in 1564. The 1566 demolition of the old choir of Santa Croce spurred the removal of the well-known *St. John the Baptist and St. Francis* by Domenico Veneziano. The entire supporting wall with the figures was preserved.¹⁶² Examples such as these, of the preservation of paintings by detachment, set the ethical precedent for modern day treatments.

Up through the eighteenth century, mural painting transfer relied upon the removal of entire masses of wall.¹⁶³ These large-scale detachments required the skills of

¹⁵⁸ Volker Schaible, "Historisches und Ethisches zur Abnahme von Wandmalerei," *Historische Technologie und Konservierung von Wandmalerei: Vortragstext der dritten Fach- und Fortbildungstagung* (Bern: Schule für Gestaltung in Kommission im Verlag Paul Haupt, 1985), 143-150.

¹⁵⁹ Milton Gendel, "Strappato, or the Art of Turning Frescoes into Easel Paintings," in *Art News*, Volume 67, Issue 6, 1968, 27.

¹⁶⁰ Schaible, 143.

¹⁶¹ Schaible, 143.

¹⁶² For further information, see The Metropolitan Museum of Art, *The Great Age of Fresco: Giotto to Pontormo*, (New York: The Metropolitan Museum of Art, 1968).

¹⁶³ The practice of removing entire walls continued sporadically after the eighteenth century and is still used today in situations requiring emergency stabilization.

architects and engineers. In Florence, architect Nicolò Gasparo Paoletti moved an entire vault painted by Poccetti.¹⁶⁴ In April 1773 he orchestrated the transfer of a vault by Ottavio Vannini inside the Villa of Poggio Imperiale, which had been set for renovation.¹⁶⁵ He was also given credit for the invention of a machine to aid in the detachment of the paintings of Giovanni da San Giovanni which were moved to the Accademia delle Belle Arte.¹⁶⁶

By the mid-eighteenth century, the techniques of *stacco* and *strappo* were being modified by Antonio Contri, a Ferrarese painter, after learning the technique of reattaching paintings to hard stone supports. Inspired by the work of Neapolitan Isodoro Frezza, Contri practiced until he mastered the removal of a very thin surface layer of intonaco, the perfect *strappo*, using methods not entirely different from those used today.¹⁶⁷ He faced paintings with glue-soaked linen and allowed them to dry for several days. After making incisions around the paintings, he detached them slowly by hand from the wall. The backs of the paintings were coated with a more dilute solution of the

¹⁶⁴ Gendel, 27. An account of this transfer, by Bottari, may also be found in the preface to the reprint of *Il riposo* by Borghini.

¹⁶⁵ When the renovation was completed in 1813, the vault was transferred for a second time by another architect, Giuseppe Cacialli. For further information, see The Metropolitan Museum of Art, *The Great Age of Fresco: Giotto to Pontormo* (New York: The Metropolitan Museum of Art, 1968).

¹⁶⁶ Volker Schaible, "Historisches und Ethisches zur Abnahme von Wandmalerei," *Historische Technologie und Konservierung von Wandmalerei: Vortragstext der dritten Fach- und Fortbildungstagung* (Bern: Schule für Gestaltung in Kommission im Verlag Paul Haupt, 1985), 143, citing Abbé de Saint-Non, "Voyage Pittoresque ou description des royaumes de Naples et de Sicile," 1782, Bd. I, 2, S.8; zit. In J. Guillerme, *L'atelier du temps*, Paris 1964, S. 144; hier in der Übersetzung des Verf.

¹⁶⁷ For further information, see The Metropolitan Museum of Art, *The Great Age of Fresco: Giotto to Pontormo* (New York: The Metropolitan Museum of Art, 1968).

same glue, backed with linen, covered with hot sand, and weighted. When the backing was dry, excess sand was removed and the facings were taken off using warm water.¹⁶⁸

Unfortunately, growing familiarity with removal techniques across Europe intensified the plundering of antiquities. Well-preserved sites, such as Pompeii in southern Italy, which was rediscovered in 1748, aroused significant interest among the rich who had both the desire and the means to obtain the ancient paintings for their own pleasure. Stone masons, builders, and sculptors worked for hire to carry out detachments. For example, one of the best known of the sculptors of the late eighteenth century, Canart, was responsible for detachments at the excavation at Herculaneum. Fascinated with the process called "*lavagna*," a traveler, Abbé de Saint-Non described Canart's technique in his journal, "*Voyage pittoresque ou description des royaumes de Naples et de Sicile*." Cuts were carefully made around the painting, which was supported by four wooden planks joined by metal latches. The supporting wall was cut from behind the painting and slate plates placed on either side of it. The whole assembly was eventually clamped together for transfer using metal straps.¹⁶⁹

By the nineteenth century, there was a growing concern regarding misuse of the technology. The nature of the technique led to damage. Traces of paint inevitably remained on the supports of detached paintings. Shrewd art dealers often profited doubly from the sale of two parts of the same painting, duping clients into believing each had an

¹⁶⁸ Schaible, 144.

¹⁶⁹ Schaible, 147.

original fresco.¹⁷⁰ In 1825, Leopoldo Cicognara, writing for the Florence paper *Antologia*, blamed overuse of the techniques for the ultimate loss of Italy's national treasures. Knowledge of the new science had been capitalized upon even by military figures who symbolically demonstrated political prowess by taking possession of works of art. Among those who Cicognara criticized was Vivant Dénon, General Secretary of the French Museum, who had been ordered by Napoleon to remove many of Rome's paintings to the collection of the Louvre.¹⁷¹ Fortunately, the failure of Napoleon's campaign in Russia prevented the loss of many of these paintings.

As with any new trend, exploitation and misuse often lead to prohibition. A growing conservatism resulted. The retention of natural texture had been frowned upon in the eighteenth and early nineteenth centuries. At that time, paintings were reattached to linen supports and flattened, losing their character as wall paintings. Not until later in the century did the loss of context and transformation of wall paintings into decorative elements become problematic.

Furthermore, the evaluation of treatments over time permitted a new awareness of technological problems. In order to preserve original surfaces, detached paintings had been coated with paraffin or waterglass, a sodium silicate liquid with binding properties.¹⁷² Unfortunately, this coating often turned to a whitish opaque film. Many

¹⁷⁰ Giovanni Urbani, "Restoration of Frescoes in Rome and Assisi" *The Connoisseur*, Vol. CXXXVI No. 549 (November 1955): 158.

¹⁷¹ Schaible, 146.

¹⁷² Ralph Mayer, *The Artist's Handbook of Materials and Techniques* (New York: The Viking Press, 1970), 361.

paintings successfully detached by the *strappo* method were ruined by post-*strappo* treatment:

- Unsuitable supports slackened over time, causing losses of the paint layer,
- Inappropriate adhesives applied to the detached paintings caused deterioration and alteration of optical properties, and
- In cases of *stacco*, remaining *intonaco* often contained moisture, allowing deterioration to continue even after detachment.

Ethical and technical concerns became grounds for discussion. Toward the beginning of the twentieth century, the removal of a painting from its context without the threat of impending destruction became undesirable and highly questionable.¹⁷³

Nineteenth and twentieth century restorations were evaluated by Leonetto Tintori in, “Methods Used in Italy for Detaching Murals.”¹⁷⁴ The *Crucifixion* by Masaccio was successfully detached using the *stacco* method circa 1860. However, paint losses occurred in the long term due to a residue of glue from the preliminary relining. The residue was removed and the paintings exhibited no further signs of deterioration. The fresco, *Pippo Spano*, by Andrea del Castagno was removed from the Villa Pandolfini in Florence in 1874. The detached painting was attached to canvas stretched on a wooden

¹⁷³ By 1866, deterioration by damp and loss by destruction of building fabric are well noted as reasons for the removal of mural paintings. Cavalcaselle proclaimed the necessity of detaching murals from walls deteriorating due to the presence of moisture. In the same year, Secco Suardo, in his manual on restoration, cites the importance of detaching frescoes by great artists in order to preserve them. For further information, see The Metropolitan Museum of Art, *The Great Age of Fresco: Giotto to Pontormo* (New York: The Metropolitan Museum of Art, 1968).

frame using calcium caseinate, a material sensitive to the action of hot water. Use of this adhesive to adhere the painting to a new support prohibited complete removal of the strappo glue. Further deterioration occurred due to humidity, causing deformation of the canvas.

Tintori also assessed the performance of his own treatments. He detached *Prato*, a fresco by Niccolo di Pietro Gerini using glue and nitrocellulose as facing adhesives. The painting was attached to a new support using a mixture of calcium carbonate, vinyl emulsion, and calcium caseinate. As assessed by Tintori, the optical properties of the painting were preserved.

Although no longer acceptable as a means by which to accumulate wealth, the practice of mural detachment was still permissible under the rationale that it was needed as an educational tool. By the beginning of the twentieth century, the original techniques of mural detachment, *stacco* and *strappo*, were being used to study artist's techniques. Paintings were removed in order to view the underlying sinopia (preparatory drawings). Entire exhibits focused on the display of detached paintings along with the drawings on rough plaster.¹⁷⁵

More recently, the use of detachment techniques has been reserved for crisis situations. Methods for applying them have benefited from the need to develop emergency preservation treatments. For example, improvements to the *stacco* method

¹⁷⁴ Leonello Tintori, "Methods Used in Italy for Detaching Murals" *Recent Advances in Conservation, Contributions to the IIC Rome Conference, 1961* (London: Butterworth's, 1961), 118-122.

¹⁷⁵ Gendel, 26-29, 64-65.

were spurred by the emergency circumstances of World War II, and again during the Florence flood in 1966. The introduction of synthetic resins as reattachment adhesives in the 1960s greatly improved remounting technology. Prior to this, the adhesive used most often for reattachment was calcium caseinate, a hygroscopic material that caused efflorescence and deformation of the paint layer in humid conditions.¹⁷⁶

Steadily throughout this century, technological innovations in visual media have aided in the preservation of context, the key to a deeper understanding of mural paintings. Photography has been recognized as a way to record the contextual information of wall paintings before detachment.¹⁷⁷ Often, the amount of time that passes between the detachment of a painting and its return to the original context requires detailed visual documentation to preserve the relationship between the painting and its setting.

As the twentieth century draws to a close, ethical concerns remain. The historical value of a wall painting depends upon the survival of its context. Original contexts provide insight for the reconstruction of a period of civilization, and to understanding its transformation over time.

Stacco a massello, *stacco*, and *strappo* must only be used if a painting risks destruction if left *in situ*. Extensive examination of a site must be carried out to determine the potential of less invasive interventions before detachment takes place. Acceptable interventions may act to reduce the speed of deterioration by eliminating its

¹⁷⁶ Eve Borsook, "Effects of Technical Developments on the History of Italian Wall Painting of the Fourteenth and Fifteenth Centuries" in *Conservation of Wallpaintings-the International Scene*, ed. Peter Burman (London: Council for the Care of Churches, 1986), 62.

¹⁷⁷ Borsook, 65.

sources and/or by addressing exacerbating structural defects. If circumstances leading to deterioration cannot be controlled, or if the structure supporting the painting is set for demolition, detachment is necessary. For example, in an archaeological context, mural detachment is one and sometimes the only means of prolonging the survival of paintings which would otherwise be destroyed during excavation.

Generally, the *stacco* method is preferred for its ability to preserve the original surface texture and optical properties of a painting. Unfortunately, when structural deterioration originates in the wall beneath the painting, it often spreads to the plaster directly underlying the paint layer. These circumstances require employment of the *strappo* method. The methodology and materials used for the three types of detachment have been implemented and modified to treat a wide variety of circumstances throughout the world. Most of the literature addresses the detachment of paintings on lime plasters, either *fresco buono* or *fresco secco*.

The following summary offers a compilation of the work of both archaeologists and conservators who have used these techniques on lime plasters, earthen plasters, and even acrylic paintings on canvas. They reflect diverse conditions and solutions resulting in individually modified treatments. Although detachment methods have been known for centuries in Italy, in many cases there was little experience to draw upon on the local level in both removal process and knowledge of the chemical makeup of the materials at hand. Consequently, there was rarely a formal basis on which to predict the results of treatment.

Case Studies

This compilation provides an overview of detachment techniques, their development over time, and the adaptations developed for specific circumstances. The majority of the treatments were not monitored over time and therefore have not been assessed in terms of appropriateness or success.

Earthen plasters

American southwest

The works of Wesley Bliss and Watson Smith in the 1930s are the most well-known in the southwestern United States. The discovery of two sites in the American southwest in the 1930s, the Kuaua Pueblo Ruins in New Mexico and the Awatovi and Kawaika-a Pueblo ruins in Arizona, provided Americans the opportunity to develop methods of removal for murals on earthen plasters over adobe walls. Both projects dealt with the problem of detaching paintings from walls with multiple superimposed layers of painted and unpainted plaster. Because these are earthen plasters, the inherent strength of lime frescoes, which facilitates the detachment process, could not be relied upon. Each project required modifications to methods developed in Italy.

Kuaua

Bliss described the preservation treatment of the Kuaua mural paintings in his 1935 thesis for the University of New Mexico and in a 1948 article for *American Antiquity*. A workman in a subterranean kiva discovered the mural paintings in 1935. The walls of the kiva, dried adobe balls set in adobe mortar, were approximately sixteen

inches thick. As many as 85 layers of thin adobe washes, each approximately one-thirtieth of an inch thick, covered the walls. Many of these had been painted.

Treatment began with the application of thin white shellac to protect the edges of the painted layers. Superficial layers were scraped away using palette knives. An accumulation of sand between the plasters and the adobe wall prompted the decision to remove the paintings before they collapsed. Plain plastered surfaces were coated with white shellac, painted areas with a dilute solution of celluloid in acetone. Three layers of tissue were applied as a facing using a wet brush. A layer of molding plaster covered the wet tissue, followed by the application of three layers of plaster-soaked burlap strips. Laths were applied to this surface and bound with more plaster-soaked burlap strips. Wooden frames, attached with more burlap and plaster, were created to fit each wall. The adobe wall was cut away from the plasters one section at a time to allow for the gradual shellacking and jacketing of the rear of the plasters. For this step the tissue layer was omitted because the back jacket was to act as a support for the painting in the laboratory. Once the base was jacketed, bolts were placed through the walls to hold the front and back jackets together. The walls were sawn apart and jacketed at the corners. The packaged walls were then transported to the Anthropology Department at the University of New Mexico.

The mural paintings exhibited no damage as a result of the jacketing or transport. Unpainted layers of plaster were scraped away to expose paintings which were then photographed and hand-copied. The surface of each painting was faced with a layer of

washed unbleached muslin attached with a solution of one quart of Eastman stripping collodian and six ounces of clear Ambroid or Duco cement. After approximately twenty minutes, the muslin-coated paintings were stripped from the wall. The reverse of each painting was covered with a mixture of adobe and casein size which, when dry, was coated with clear Ambroid. The paintings were glued to a wallboard coated with the adobe/casein mixture. The muslin was rolled back upon itself to expose the paintings.¹⁷⁸

After each layer was detached, its underlying undecorated layers were scraped down to the next painting. All paintings were displayed in their corresponding positions.¹⁷⁹ Follow-up condition reports revealed that the paintings were in poor condition. The instability of the wallboard support as well as the poor aging properties of the nitrocellulose medium used to remount the paintings exacerbated deterioration of the paintings.¹⁸⁰

¹⁷⁸ No reference was made to the softening of the facing adhesive prior to its removal or to the treatment of surface residue.

¹⁷⁹ Wesley Bliss, "Preservation of the Kuaua Mural Paintings" *American Antiquity* Vol. XIII, no.3 (1948): 218-223.

¹⁸⁰ Constance S. Silver, "Architectural Finishes of the Prehistoric Southwest: A Study of the Cultural Resource and Prospects for its Conservation" (master's thesis, Columbia University, 1987), 171.

Awatovi

The Awatovi expedition ran for five field seasons from 1935-1939, under the direction of Watson Smith in the Jeddito area of Arizona. Mural paintings were discovered in kivas constructed of stone blocks or sometimes adobe brick, held together with adobe mortar. A preparatory coat of coarse gray adobe plaster covered the surface of some of the walls. Successive layers of a fine textured reddish-brown plaster composed of calcareous material and iron-stained quartz sand mixed with water coated the walls. Layers ranged from one to six millimeters in thickness. As at Kuaua, super-imposed painted decorations were found. All pigments but black were inorganic.

Smith and the excavation crew were familiar with the detachment methods employed at Kuaua but full-scale removal of the walls from Awatovi could not be carried out due to their sheer number. The walls were treated *in situ*. The removal of undecorated plasters was carried out using penknives and scalpels. As at Kuaua, paintings were photographed and hand-copied. Methods applied at Kuaua provided the foundation for the removal of paintings at Awatovi.¹⁸¹

Cracks and holes were filled with a patching compound of plasticized calcareous sand. After extensive testing with a number of different facing adhesives, a mixture of consisting of: 100cc Alvar 7-70, 100cc Acetone, 60cc ethylene dichloride, and 20cc dibutylphthalate was chosen. One layer of this mixture was applied to the surface of the

¹⁸¹ Watson Smith, "Kiva Mural Decorations at Awatovi and Kawaika-a" in *Papers of the Peabody Museum of American Archaeology and Ethnology, Harvard University* (Massachusetts: Peabody Museum, 1952), 13-59.

paintings and permitted to become tacky or in some cases, dry. After the application of a second layer of adhesive, strips of boiled unbleached linen were pressed against it. When the facings were completely dried, they were removed by pulling down from the top at a 45° angle from the wall surface. A knife was used to help separate the muslin from the plaster. Unpainted plaster was scraped away until the next painting was reached. The detached paintings were applied to glue-sized Untempered Masonite Presdwood, mounted on a pine frame to reduce shrinkage. The surface of each panel was sanded and coated with a glue/sand size composed of one part Cologne glue soaked in two parts water, 1cc clove oil, 1cc carbolic acid, 1 cc thymol in a 50% alcohol solution, and 10 cc santophen in a 10% water solution. This mixture was applied to the back of each painting. A synthetic plaster composed of glue, water, and plaster that had been shipped from the site, was prepared and applied to the back of the painting and permitted to set. Facings were removed by spraying the surface of the upright panels with acetone until all the glue had dissolved. The surface was then sprayed with a 4% tincture of formaldehyde in alcohol to harden the surface. These paintings were found to be in stable condition even after fifty years.¹⁸²

Soviet Middle Asia

Soviet Middle Asian paintings found in the 1940s and 1950s were preserved by P.I. Kostrov of the Hermitage Museum, who developed techniques based on the results of conservation treatments carried out on earlier monumental sites. The paintings were

¹⁸² Silver, 171.

executed on loess plasters. Deterioration of the paint layer and ground caused the plasters to break apart when attempts were made to separate them from the wall. They were consolidated with a synthetic resin dissolved in a xylene base. The paintings were cut into sections and faced with two layers of gauze adhered with PVA. Grooves were worked behind the surfaces of the sections to be detached. Excess loess plaster was disposed of through one of the sides. Wooden frames were propped tightly against the painted surfaces and the paintings were detached using chisels, hammers, long knives, and small picks. The back of each painting was coated with polybutylmethacrylate followed by a wax-colophony mixture and two layers of gauze. The same wax-colophony mixture was used to attach the paintings to new supports constructed from galvanized iron sheets attached to wooden subframes. PVA facings were removed with alcohol and the paintings were exhibited at the State Hermitage Museum.¹⁸³ This research provided the basis for later conservation methods developed for the conservation of clay plaster, loess, loess-gypsum, and partially gypsum sculptures excavated in Middle Asia.¹⁸⁴

Lime plaster on mudbrick

Tumacacori National Monument, Arizona

In “Conservation of Painted Lime Plaster on Mud Brick Walls at Tumacacori National Monument, U.S.A.,” Anthony Crosby briefly describes the 1977 detachment of

¹⁸³ P.I. Kostrov and E.G. Sheinina, “Restoration of Monumental Painting on Loess Plaster Using Synthetic Resins” *Studies in Conservation* Vol. 6, Numbers 2 and 3 (August 1961): 90-102.

¹⁸⁴ B.J. Stavisky and N.N. Zhukova, “Parallel Progress in Restoration and Archaeology: Discovery and Restoration of Monumental Painting and Sculpture on a Loess Ground” in *ICOM Committee for Conservation 10th Triennial Meeting Washington, DC, USA Preprints* (United States: International Council of Museums, 1993) 395-398.

a severely deteriorated paint film from the earthen plaster walls of a Spanish Colonial Mission Complex. The friable painted layer was stabilized with a dilute solution of polyvinyl acetate prior to detachment by the strappo method. Facings of cheesecloth and muslin were used to detach the paint film. Although some losses occurred during separation and removal due to the extreme friability of the paint, the treatment was deemed a success, and the painting remounted on a fiberglass support.¹⁸⁵

China

In China, mural paintings with two types of support have been found in ancient graves and grotto temples. Their treatment was described in Qi Yingtao's "Studies on Conservation of the Grotto Temples and the Mural Paintings of Ancient Graves in China."¹⁸⁶ Rock, brick or stone walls were sometimes coated with a layer of mud and straw plaster, followed by a lime rendering ranging from three to eight centimeters thick. Paintings were executed on the lime plaster. Another type of painting was executed directly on the wall or on top of a fine coat of limewash. Both types exhibited interlayer detachment, flaking, and cleavage of the painted layer. Transfer methods were developed for those that could not be preserved *in situ*.

¹⁸⁵ Anthony Crosby, "Conservation of Painted Lime Plaster on Mud Brick Walls at Tumacacori National Monument, U.S.A.," in *Third International Symposium on Mudbrick (Adobe) Preservation* (METU: Offset Printing Workshop, 1980), 59-73.

¹⁸⁶ Qi Yingtao, "Studies on Conservation of the Grotto Temples and the Mural Paintings of Ancient Graves in China" in *International Symposium on the Conservation and Restoration of Cultural Property-Conservation and Restoration of Mural Paintings (1), November 17-21, 1983, Tokyo, Japan* (Japan: Tokyo National Research Institute of Cultural Properties, 1984), 19-29.

Transfer techniques were divided into four categories.

- Tearing down: removal of the wall along with the painting, used specifically when individual paintings appear on each brick.
- Sawing to remove: a saw is used to cut down between the wall and the rendering
- Prizing to remove: a lever is inserted to gradually increase the size of a pre-existing void between the rendering and the wall until the painting is completely detached
- Shocking to remove: a chisel is used to slowly jab away the mud layer, carried out in cases when the rendering and wall are well adhered to one another.

Sawing, supplemented by the other techniques, was the primary method used to detach mural paintings. Yingtao only briefly mentions “adhering with pasted cloth to remove,” a technique whose name implies a similarity to the *stacco* or *strappo* methods.

The mural paintings, often quite large, were first divided into sections. Double layers of facing, one paper, the other fabric, were attached in early treatments with peach glue, and subsequently with polyvinyl butyral. The backs of detached paintings were cleared of fragments and coated with a layer of polyvinyl acetate emulsion. Renderings were most often reconstructed using a mixture of polyvinyl acetate emulsion, lime, and hemp fiber. To improve shock resistance, cloth was adhered to the rendering using epoxy resins. The condition of the paintings after detachment was not discussed.

India

As with the Chinese examples described above, the earliest wall paintings discovered in India are painted directly on the rock surfaces of caves. Later examples were executed on earthen plaster bases with white lime, gypsum, or kaolin grounds. From about the sixth century A.D. onward, lime and sand plasters were used. Both tempera and true fresco techniques have been discovered.

Transfer methods were developed in India to preserve paintings exhibiting severe deterioration.¹⁸⁷ Two such methods were used at the Rangmahal Palace at Chamba:

- Detachment of paintings with renderings in tact: for paintings executed on a thick lime plaster
- Detachment of only the paint layer: for paintings executed on clay plaster

Paintings were faced with muslin using PVA emulsion. A second facing of heavier cloth was adhered with animal glue. Saws, chisels and pointed bars were used to cut the panels free. Paintings were reattached to an aluminum frame/plaster of Paris support. Hot water was used to remove the outer facing, ethyl alcohol, the inner.

Paintings were reassembled in their original order and displayed at the National Museum. Paintings executed on clay plasters were too fragile to withstand the cutting procedure described above. The paint layer was removed and fixed on a support consisting of cloth and hard board attached with a casein–lime adhesive.

¹⁸⁷ O.P. Agrawal and Kamal K. Jain, "Problems of Conservation of Wall Paintings in India" in *International Symposium on the Conservation and Restoration of Cultural Property-Conservation and Restoration of Mural Paintings (1)*, November 17-21, 1983, Tokyo, Japan (Japan: Tokyo National Research Institute of Cultural Properties, 1984), 31-40.

Another palace complex located in Kulu required the detachment of one of its murals. Water infiltration had severely deteriorated an otherwise hard lime plaster wall. Double layer facings of muslin and a heavier cloth were applied with PVA emulsion. Panels were cut out in 2-by-2-foot sections and reassembled for display at the National Museum at New Delhi. Facings were removed with ethyl alcohol. The treatments were deemed successful.

Bulgaria

Archaeological excavations in Bulgaria revealed painted tombs belonging to the Thracians, an ancient people who settled around the Balkan peninsula until around the seventh century A.D. One of these, the Maglish Tomb, dates from the beginning of the second century B.C. A thick mud-lime-sand preparatory plaster coated the uneven surfaces of its brick walls. A ground layer consisting of sand, marble dust, and lime, and a finish layer consisting of marble dust and lime followed this. Detachment and deterioration of the paintings were caused primarily by a lack of adhesion and cohesion of the preparatory layer. The wall paintings existed mainly as fragments, some still adhering to the wall, most lying on the ground. In order to facilitate reconstruction, the few fragments remaining adhered to the walls were detached. The procedure was carried out without a facing due to the friability of the paint surface. Poor adhesion between the plaster and the brick wall simplified the process. A net was used to catch falling fragments during removal. Once the surfaces had been cleared of dirt and salts, the paint consolidated with multiple coats of Acryloid B-72, 0.5-3%, and the backs cleaned, the

fragments were reassembled for mounting. A metal structure embedded in new plaster composed of lime, sand, marble dust, asbestos fibers, and 10% PVA, was attached to the backs of the fragments.¹⁸⁸

Lime plaster/frescoes

Montenegro

An earthquake in Montenegro in 1979 caused extensive damage to the Complex of Monastery Podlastva. Mural paintings, in many cases seventeenth century frescoes covering fifteenth century frescoes, suffered extreme damage, some requiring detachment. Surfaces were fixed with Acryloid B-72 prior to detachment by the *stacco* method. Two linen facings were attached with *colletta*. The paintings were successfully separated using vibration. Each painting was reduced to a thickness of 2-to-5-millimeters and attached to a new support made from a lime-casein adhesive with a 10% solution of polyvinyl acetate and 3 layers of linen. This was applied to a second support consisting of layers of Araldite, glass wool, and polyurethane sheets. Warm water was used to remove the facings. *Colletta* residue was removed using a warm water pulp poultice covered by a hot water bottle. More than twenty-five square meters of wall paintings were detached and remounted beginning in 1983. The procedure was considered a success.¹⁸⁹

¹⁸⁸ A detailed report of this project can be found in: Zdravko Barov, "Thracian Painted Tombs: Technical Notes and Conservation Procedures" in *International Symposium on the Conservation and Restoration of Cultural Property-Conservation and Restoration of Mural Paintings (1), November 17-21, 1983, Tokyo, Japan* (Japan: Tokyo National Research Institute of Cultural Properties, 1984), 197-208.

¹⁸⁹ Zdravko Gagović and Aleksandar Čilikov, "The Report on the Works on the Complex of Monastery Podlastva from July 5-October 2, 1983" (ICCROM Library, photocopy), 1-3.

Catalonia

Sometimes the removal of a wall painting is dictated by the state of preservation of its surroundings. In 1982, several Romanesque frescoes were found during restoration work at the Church of Saint Tomàs de Fluvià in Catalonia, beneath several coats of paint and whitewash and a false vault.¹⁹⁰ More than 60% of the painted surfaces were separated from the wall. Multiple layers of different periods were super-imposed on the original. Previous water infiltration caused erosion of the mural paintings and the crystallization of salts. Although the sources of these problems had been eliminated, the presence of moisture due to condensation was found to be an inevitable circumstance within the upper portions of the building that housed the paintings. The paintings, faced with *colletta*-impregnated cloth strips, were detached from the walls using the *strappo* technique, although a *stacco*-like condition sometimes resulted. Each painting was reattached to canvas, and the whole, with the addition of an isolating layer, was attached to polyester and fiberglass soffits. In December 1986, the paintings were returned to their original locations and reattached using stainless steel tubes. A twelve-centimeter distance was retained between the mural and the wall to prevent any further deterioration by damp. The author, although opposed to the detachment of mural paintings, noted that as a last resort, the treatments were necessary and well worth the effort.

¹⁹⁰ Treatment of these paintings was described by Josep Maria Xarrié in "Pintures Murals de Sant Tomàs de Fluvià" in *De Museus: Quaderns de Museologia i Museografia* Issue 1 (1988): 116-119 and English summary.

England

The transfer of the medieval crypt vault paintings at Rochester Cathedral in 1984-1985, is a good example of both the detachment of an extensive area of painted plaster and its reattachment *in situ*. The paintings were partially separated from their grounds, and actually hung from the vault in some places. Excessive moisture and the previous application of an organic fixative had severely darkened them. The crypt dates from two periods ranging from 1080 to 1227. Its use as a coal storage, as well as its proximity to a gypsum factory resulted in the deposition of soot and gypsum particles on the surface of the paintings. These were trapped by a hard crystalline layer of salt, which had formed on the surface due to the movement of moisture through the vault. The friability of the original rendering would not allow for the consolidation of the painting or its limewash ground. Transfer of the paintings to a new support was determined to be the only viable solution.

The vault and soffits were faced in their entirety with a triple layer of silk crepeline and document tissue strips adhered with viscous water-soluble glue. The location of cuts was marked in advance to coincide with appropriate elements within the painting. Ninety sections of the painting were removed using a scalpel to incise the surface. The badly deteriorated plaster rendering of the vault was removed down to the rubble structure in order to build up a new sound plaster support for the painting. Fragments of the lime coat and mortar were removed from the back of each painting section. An adhesive mortar consisting of a 1:1 mixture of very fine sieved sand and

equally fine sieved lime was used to reattach the paintings to the new coarse support. A coat of limewash was applied to the backs of the painting to encourage adhesion to the adhesive mortar. A three-millimeter thick layer of the mortar was then applied and the paintings were pressed into place using modified printers' rollers. After one day, the facings were removed with steam. The successful detachment and subsequent reattachment *in situ* allowed the conservators to progress to the next stage of treatment, the removal of the overlying crystalline salt layer.¹⁹¹

Rome, Italy

The Crypt of the Basilica of San Lorenzo Fuori le Mura was discovered in Rome circa 1970. During the following years, the eighth century frescoes suffered severe deterioration due to the drastic environmental changes brought on by exposure. The mural paintings were discovered on water-saturated walls composed of brick, stones, pozzolana, and lime. The plasters were detaching from their supporting walls and exhibited a complete lack of cohesion. The delaminating paint layer lacked cohesion and adhesion and was encapsulated by both soluble and insoluble salts. After careful consideration, a decision was made to detach the paintings. Prior to detachment, the paint layer was fixed with an acrylic emulsion, Primal AC 33. Heat was applied in an effort to dry the surface. Two cloth facings were attached using Acryloid B-72 in a 35% solution in lacquer thinner. Paintings were detached by the stacco method. The back of each

¹⁹¹ David Park and David Perry, "Rochester Cathedral: Conservation of the Crypt Vault Paintings," in *Case Studies in the Conservation of Stone and Wall Paintings, Preprints of the Bologna Congress, 21-26 September 1986* (London: The International Institute for Conservation of Historic and Artistic Works, 1987), 182-185.

painting was reinforced with two layers of cheesecloth and one of hemp canvas attached with lime caseinate. A support consisting of fiberglass, expanded polyurethane, and an isolating layer of cork was then attached with a mixture of PVA emulsion and calcium carbonate. Facings were removed with cellulose pulp poultices and lacquer thinner. Salts were removed, losses were filled and patinated, and a 2.5% solution of Acryloid B-72 in lacquer thinner was sprayed on in one application.¹⁹² Treatment results were satisfactory.

Florence, Italy

One of the largest detachment programs was initiated when torrential rains caused the flooding of the Arno River in Florence on November 4, 1966. Many of the city's most important buildings and collections were affected. The Basilica of Santa Croce, the Duomo, the Uffizi Gallery, the National Library, the National Museum of History and Science, the homes of Dante and the Medicis, and the Palazzo Vecchio all suffered extensive damages, with flood waters reaching as high as ten to twenty feet.¹⁹³ The plaster supports of some paintings suffered damages due to direct contact with the floodwaters. Others, which had been situated high above the path of the water, began to deteriorate due to the effects of capillary action. Moisture spread throughout the walls, encouraging the growth of molds and fungi. Salts, often concentrated in the grounds

¹⁹² A full report of this treatment can be found in: Paul M Schwartzbaum, Ippolito Massari, Giovanna Pignatelli and Carlo Giantomassi, "Approaches to the Conservation of Mural Paintings in Underground Structures, Case Studies of Recent Projects by ICCROM Consultants and Staff" in *International Symposium on the Conservation and Restoration of Cultural Property—Conservation and Restoration of Mural Paintings (1), November 17-21, 1983, Tokyo, Japan* (Japan: Tokyo National Research Institute of Cultural Properties, 1984), 41-58.

¹⁹³ Anon., "Preserving a Priceless Art Treasure" *Rohm and Haas Reporter* (Philadelphia: Rohm & Haas Co., Summer 1974), 3-4.

below churches with burial grounds, were carried by the moisture up through the walls, where they began to crystallize, causing losses within the painted surfaces. In many cases, detachment of the frescoes was the only option. More than 2,300 square meters of mural paintings were dried with portable heaters and detached from the walls during an eighteen month period of continuous work by the Restoration Laboratories of the Fortezza di Basso in Florence.¹⁹⁴ Their technique, called *trasporto*, is similar to the traditional *strappo* method. The frescoes were coated with animal glue and a layer of gauze-like canvas. When the glue had dried, the canvas was “pulled off,” taking only a thin layer of the painted wall with it. According to the conservators, none of the pigments were lost. Upon detachment, paintings were rolled and taken to the Restoration Laboratories for treatment. New supports consisted most often of a combination of calcium carbonate, Rhoplex acrylic emulsion as a binder, and a glass fiber canvas.¹⁹⁵ References to this treatment did not offer an assessment of the end result.

India

Two directly superimposed historically significant paintings were discovered at the Brihadeeswara Temple at Thanjavur, India. The overpainting belonged to the Nayakka Period dating to the sixteenth century, the underlying layer to the Chola Period dating to the eleventh century. Rather than sacrifice the later painting, as had been done in earlier treatments, a decision was made to modify the traditional *stacco* process. Both

¹⁹⁴ Milton Gendel, “Strappato, or the Art of Turning Frescoes into Easel Paintings” *Art News*, Vol. 67, no. 6 (1968): 26.

¹⁹⁵ Anon., “Preserving a Priceless Art Treasure” *Rohm and Haas Reporter* (Philadelphia: Rohm & Haas Co., Summer 1974), 9-10.

paintings had been executed on lime plaster, each with a two-part ground/finish sequence. The later painting was faced with layers of gauze and canvas using a 20% solution of polyvinyl acetate. Detachment, carried out using rubber tipped chisels and a wooden mallet, was facilitated by the exceptionally smooth surface of the earlier painting. The detached painting was attached to canvas and a sheet of polyurethane foam using polyvinyl acetate emulsion. The whole was then attached to a sheet of fiberglass mat using an epoxy resin adhesive. Facings and residue were removed using a 9:1 solution of toluene and acetone. Following the consolidation of the earlier Chola layer, both were displayed. The project, as assessed by the conservator, was a complete success.¹⁹⁶

Acrylic on canvas

Canada

Two large acrylic murals painted in 1956 by Oscar Cahén on acrylic-grounded cotton canvas, were removed from the Imperial Oil Building in Toronto, Canada in 1979. Their supporting structures were set for demolition and renovation.¹⁹⁷ The 9'9" x 22'6" and 8'6" x 29'8" paintings were adhered with contact adhesive to terra cotta tile brick walls coated with ½"-1" thick cement (expanded metal lathe embedded in some areas) and a skim coat of white plaster. Facings of wet strength tissue were applied with *colletta*. A modified *strappo* method was used to roll the paintings on to large diameter

¹⁹⁶ The full report on this operation may be found in S. Subbaraman, "Separation of Two Layers of Mural Painting by Modified Stacco Process" *Role of Chemistry in Archaeology* (India: The Birla Institute of Scientific Research, 1991), 76-80.

¹⁹⁷ Janice Antonacci and Virginia Caswell, "The Emergency Removal of Two Large Murals" in *Papers Presented at the Art Conservation Training Programs Conference, April 28 & 29, 1980* (Newark, Delaware: The Program, 1980) 127-145.

reinforced cardboard tubes covered with cotton fabric. The mural canvases were carefully detached and the front edges stapled to the cardboard tubes. As each tube was turned, the bond of the contact adhesive was severed manually with scalpels. Polycotton fabric was interwoven into the roll to prevent the contact adhesive residue on the reverse of the painting from sticking to the facings. The rolled paintings were protected with fabric and polyethylene to prepare for transport and storage. Although additional testing was prohibited by time constraints, the authors noted that detachment methods would not have been significantly altered. The paintings were left in storage with their facings intact. No mention is made of facing removal or follow-up evaluation.

Conclusion

Comprehensive research programs have been carried out to evaluate the materials most often used to facilitate the detachment of mural paintings. Both traditional and synthetic materials have been studied. Giorgio Torraca and Paolo Mora summarized a comprehensive study of fixatives and consolidants in “*Fissativi per Pitture Murali*.”¹⁹⁸ The uses and ideal properties of fixatives are discussed for both dry and humid environments. Synthetic and traditional fixatives were evaluated for ease of use, adhesion, resistance to aging, resistance to abrasion, resistance to biological attack, solubility, and effects on optical properties. The report includes a description of the ideal properties of a fixative to be used prior to detachment. A great deal of this information

¹⁹⁸ Giorgio Torraca and Paolo Mora, “Fissativi per Pitture Murali” in *Bollettino dell’Istituto Centrale del Restauro* (Italy: ICCROM, 1965), 109-132.

may also be found in *The Conservation of Wall Paintings* by Paolo and Laura Mora and Paul Philippot.

“Some Further Testing of Materials Used During the Restoration of Mural Paintings,” compiled by Margaret Hey, includes the research of several notable investigators.¹⁹⁹ Contributions include the results of microbiological analysis of experimental supports; evaluations of fixative solutions, adhesives, and support materials; and the weathering test results of commonly used materials. This report is specifically geared toward materials used in the detachment process.

“Architectural Finishes of the Prehistoric Southwest: A Study of the Cultural Resource and Prospects for its Conservation” written by Constance S. Silver in 1987 includes an extensive study of both traditional and synthetic materials used for the detachment of wall paintings.²⁰⁰ Painted earthen plaster facsimiles were created in a conservation laboratory. Methods and materials for detachment were modified and tested for use on adobe plasters. Detailed assessments of each treatment are included.

¹⁹⁹ Margaret Hey, *Some Further Testing of Materials Used During the Restoration of Mural Paintings* (Amsterdam: ICCROM, 1969), 1-29.

²⁰⁰ Constance S. Silver, “Architectural Finishes of the Prehistoric Southwest: A Study of the Cultural Resource and Prospects for its Conservation” (master’s thesis, Columbia University, 1987), 172-190.

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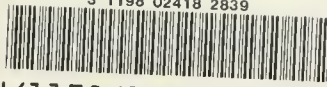
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